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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

OPTICAL STORAGE SYSTEM
FOR
SHIPBOARD SUPPLY DOCUMENTS

by

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and
Edwin A. Victoriano

December, 1989

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This thesis attempts to find a better alternative to the manual storage of material issue and receipt documents on the Navy's aircraft carriers and submarine tenders. The objectives were to develop a system that would significantly reduce the labor time required to file the documents, reduce the required storage volume, increase file accuracy, and increase access to file information. Alternatives using current document storage technology were analyzed. A PC-based optical document storage and retrieval system is proposed as the optimum alternative.

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Optical Storage System for Shipboard Supply Documents

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ABSTRACT

This thesis attempts to find a better alternative to the manual storage of material issue and receipt documents on the Navy's aircraft carriers and submarine tenders. The objectives were to develop a system that would significantly reduce the labor time required to file the documents, reduce the required storage volume, increase file accuracy, and increase access to file information. Alternatives using current document storage technology were analyzed. A PC-based optical document storage and retrieval system is proposed as the optimum alternative.

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I. INTRODUCTION

A. BACKGROUND

When a U.S. Naval ship leaves port it carries very sophisticated weapons, computers, radar systems, and large volumes of paper. Sailors receive extensive training to operate and maintain the complicated equipment. But along with the equipment comes tons of publications, reference manuals, and working documents that the ship's sailors need to operate, maintain, and monitor the use of the equipment on a daily basis. Just controlling the paper flow can be a full time job for some of our highly trained sailors.

V. Adm. Joseph Metcalf, prior to his retirement as Deputy Chief of Naval Operations for Surface Warfare in 1987, challenged the Navy's surface warfare community to reexamine old design concepts. He initiated the "Revolution at Sea" studies to define a new family of warships for the 21st century. [Ref. 1:p. 59] The "revolution" began on 20 September 1986 when he took part in commissioning ceremonies aboard USS Bunker Hill (CG 52). Although V. Adm. Metcalf enjoyed the ceremony, he returned to Washington disturbed. Aboard the ship he noted a half-dozen technical libraries, each with highly paid technicians acting as full time librarians. They were not doing what they were trained to do. They were buried in technical manuals, instructions, notices, and all the other printed sources of information that are vital to the operation and safety of the ship. [Ref. 2:p. 14] "We don't train sailors to be registrars and correctors of publications. I mean, that's dumb. I want those guys worrying about fighting, not worrying about keeping up the publications." [Ref. 3]

V. Adm. Metcalf expressed the idea that a warship should initially be designed completely full of missile launchers. For each additional system added to the ship, there should be justification as to why that system is more important than the missile launcher(s) it replaced. Since a surface combatant's payload is its ordnance, and because warships are volume rather than weight limited, the percentage of enclosed volume dedicated to warfighting or payload volume is a reasonable measure of a warship's potential combat effectiveness. Figure 1-1 shows the trend in payload volume aboard modern surface combatants. [Ref. 1:p. 59] From World War II through the mid-1960's the payload volume on combatants steadily increased, but during the late 1960's and 1970's the payload volume relative to total volume decreased considerably. This trend helped to motivate the Revolution at Sea concept. A ship's warfighting capability, or its ability to increase ordnance on target, can be improved by a variety of methods: decreasing overhead volume, decreasing overhead time, increasing probability of hit, increasing the ship's survivability, and increasing the ship's ability to fight while damaged. This study will only deal with the first two methods.

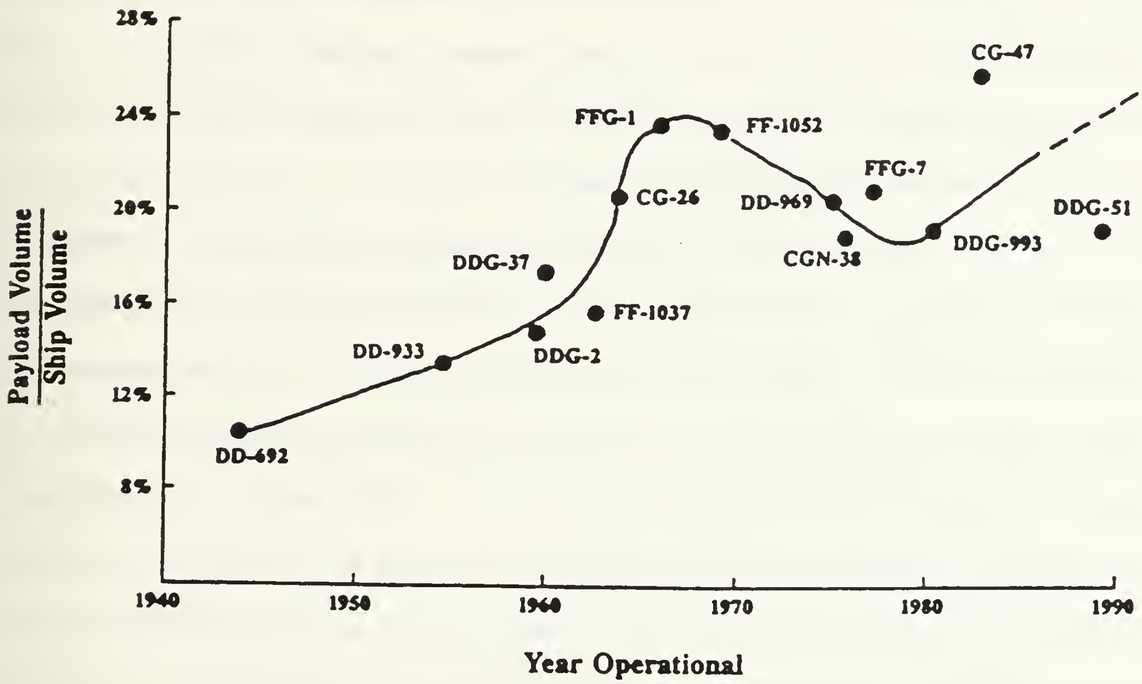


Figure 1-1. Trend in Payload Volume Aboard U.S. Navy Surface Combatants

Source: Ref. 1

1. Decreasing Overhead Volume

A ship's warfighting potential can be related to the number of weapons and the amount of ordnance it carries. We might consider the total volume of a warship as consisting of ordnance (the volume occupied by the weapons themselves, the ammunition, and the weapons' combat control systems) and overhead. The overhead volume is defined as the ship's space that is primarily devoted to direct crew support, such as berthing, messing, sanitation, passageways, storerooms, and administrative office space, much of which is also a function of crew size. If the overhead space can be decreased, the volume available for ordnance can be increased. [Ref. 1:p. 60]

2. Decreasing Overhead Time

In addition to reducing non-warfighting overhead space, ordnance on target can be increased by decreasing overhead time. Overhead time is defined as those working hours spent by sailors performing non-warfare functions in lieu of warfare-relevant activity. Cleaning, painting, cumbersome administrative procedures, and waiting in line for services, such as pay, food, medical, and administrative services, are examples of overhead time. Such time could be more appropriately used for combat system training or other functions which relate directly to placing ordnance on target. Thus, decreasing overhead time can be a useful means of increasing ordnance on target. [Ref. 1:pp. 60-61]

V. Adm. Metcalf consulted his peers in OPNAV, and on 24 December 1986 they signed a joint memorandum that implemented a program to examine the information storage requirement aboard ship. The program addressed information storage in the form of records, publications, engineering drawings, technical data, etc., and explored alternative methods of providing information storage. The memo noted that the program would provide a plan of action for CNO approval, leading to the use of state-of-the-art information management and storage technology. [Ref. 2:p. 14]

V. Adm. Metcalf assigned Capt. Russell F. Anderson, Head of the Surface Warfare Combat Readiness Division of the admiral's staff, as Chairman of the working group for the paperwork reduction program. The group hired a contractor to go to two surface ships, USS Wadsworth (FFG 9) and USS Vincennes (CG 49), a submarine, USS Atlanta (SSN 712), and an Aircraft squadron, VA-105. They weighed not only the paper aboard, but also the storage cabinets and shelves used to store or hold the paper. According to Capt. Anderson the survey "was really an eye-opener. For instance, on the FFG 7 class, we had 20.6 tons. About one-third of that was above the 01 level, which aggravates stability problems, and the weight certainly eats up the fuel, reducing endurance." The study also identified 10 tons in the forward third of a submarine and 37 tons in an Aegis cruiser. [Ref. 2:pp. 14-15]

The study identified the physical locations of the paper, how much it weighed, its volume, who used the data, how frequently it was used, how accurate the documents had to be, how often they were updated, and who originated them. The paper was divided into three categories: reference material (representing 55% of the documents studied), working documents (about 25%), and paper stock material (20%). The categories were chosen because they lend themselves to different kinds of paper-saving technologies that can be used to reduce or eliminate the requirement to store paper in ships.
[Ref. 2:p. 15]

a. *Paper Reduction Becomes Law*

The paper reduction goal does not just belong to the Navy; the entire federal government shares the goal. In 1980 the Paperwork Reduction Act was enacted into public law. The law states the following purposes:

1. To minimize the Federal paperwork burden for individuals, small businesses, State and local governments, and other persons.

2. To minimize the cost to the Federal Government of collecting, maintaining, using, and disseminating information.

3. To maximize the usefulness of information collected, maintained, and disseminated by the Federal Government.

4. To coordinate, integrate, and to the extent practicable and appropriate, make uniform Federal information policies and practices.

5. To ensure that automatic data processing, telecommunications, and other information technologies

> are acquired and used by the Federal Government in a manner which improves service delivery and program management, increases productivity, improves the quality of decision making, reduces waste and fraud, and wherever practicable and appropriate, reduces the information processing burden for the Federal Government and for persons who provide information to and for the Federal Government. [Ref. 4]

b. Information Needed--Not Paper

Although our Navy's ships carry several tons of paper, it is not the paper itself that the ship needs, but the information contained on the paper. Typical types of information required on board ships are the following:

1. Reference information to operate and maintain the ships weapons or propulsion systems.
2. Instructional information used to provide guidance on performing various shipboard duties.
3. Audit trail information to record financial or material transactions or proof that certain crucial duties were performed (ship's logs).
4. Legal documents such as contracts for material or services that contain required signatures.

Storing large amounts of information on paper requires allocating large volumes of space to store the paper. It also takes a considerable amount of time to sort and place the information in a sequence that will allow personnel to retrieve it later in timely fashion. Due to the large volume of documents to be filed, large backlogs develop, contributing to lost or misplaced documents--or information.

V. ADM. Metcalf believes that achieving a "paperless" ship will have to be affordable, but he says cost-effectiveness is not the prime motivation for this effort. "I look at pounds of paper in terms of being able to put more ordnance or more fuel on ship," he said. "We do not shoot paper at the enemy. If you fill a ship with paper, you obviously can't shoot ordnance." [Ref 2:p. 16]

B. SCOPE

In line with V. Adm. Metcalf's and DOD's pursuit for the 'Paperless Ship' and the 'Paperless Pentagon,' this study attempts to find ways to reduce the paper storage of some of the audit trail information mentioned above. Specifically, the study will focus on the storage of material issue and receipt documents on aircraft carriers and submarine tenders. We describe the current filing system -- how the issue and receipt information is input to the shipboard supply computer, how the documents are filed, the average number of documents processed per month, the time it takes to file the documents, the amount of storage space required, and the problems associated with manual filing. We then propose alternative means to store the information, and we evaluate these alternatives.

We discuss the current technology available to automate this filing system using an optical laser scanner to capture the document image, a computer to digitize the image, and optical disks for high capacity storage.

We apply the new document storage technology to a Navy shipboard Stock Control Division. We discuss the benefits and limitations of the proposed system to the ship in terms of its contribution to the warfighting mission and helping to attain supply management goals.

We propose a system configuration for an aircraft carrier or submarine tender, based on their high processing volumes. We then perform a cost/benefit analysis that compares the costs of the current manual filing system to the costs of the proposed automated filing system. We also identify several intangible benefits of the proposed system over the manual system.

While specific vendors and products are occasionally mentioned as representative of particular document and retrieval methodologies, no attempt is made to provide a complete list of all vendors and products. Also, the mention of a given product does not constitute an endorsement, nor does the omission of a specific product imply any lack of value in it.

C. METHODOLOGY

Research on hardware technology and application software was conducted using trade journals, periodicals, and interviews with vendor representatives. We researched hardware and software capabilities, processing times, shipboard suitability, maintainability, space requirements, and costs.

Research for the current shipboard filing system was conducted on an aircraft carrier at NAS Alameda and two submarine tenders at Naval Submarine Base San Diego. Information was obtained through onboard interviews with the supply officer and stock control personnel and time and motion analysis of the current manual filing process.

We examined the current filing process by measuring the time it took five different people, ranging from an E-2 to an O-3, to manually file 100 documents each into the filing cabinets. We also measured the time it took three people to retrieve 50 documents each from the filing cabinets, and the percentage of documents not found. We then determined the average filing and retrieval times per document.

Before observing the filing process we tried to promote an atmosphere of normal everyday operation. We instructed the sailors to file documents at a normal pace as though they were not being observed. We instructed them to accommodate any routine disruptions, such as answering the phone, as long as the interruptions would not last more than one or two minutes. Even with these instructions, we feel that the observed filing times are faster than they would be under normal conditions because we limited disruption time length, and the filers (E-2 to E-5) were *observed* (by (O-3's). We also feel that shipboard filing times will vary depending on a given day's activities.

One of the ships we visited had just installed a PC-based optical document storage and retrieval system called Ultra Retrieve (Version 1) developed by CACI, Inc. This system does not contain all of the features we recommend for the proposed system. To provide input data for the estimated document file and retrieval times for our proposed system, we measured the time it took one operator to file 100 barcoded documents and 100 non-barcoded documents using Ultra Retrieve, Version 1. These time and motion analysis results are contained in Appendix B.

Other information obtained aboard ship were the document's storage space requirements, and problems associated with the manual paper filing system. The average number of issues and receipts processed monthly aboard ships were obtained from Commander Naval Air Force, U.S. Atlantic Fleet, Commander Naval Air Force, U.S. Pacific Fleet, and Commander Submarine Force, U.S. Pacific Fleet (see Appendix C).

II. CURRENT SHIPBOARD RECEIPT AND ISSUE SYSTEM

To understand the receipt and issue document flows, and the uses for the information contained on the documents, a general knowledge of the current shipboard receipt, issue, document filing, and financial and inventory reconciliation procedures is required. These procedures, plus some definitions of commonly used terms and acronyms, are presented in this chapter.

A. DEFINITIONS

1. DTO Receipts

Requisitioned material that is received for direct turnover (DTO) to the customer.

2. Stock Receipts

Requisitioned material that is received for eventual storage in the ships storerooms to meet future demand for the items.

3. SUADPS

Shipboard Uniform Automated Data Processing System. Computer software that provides shipboard mechanized inventory control, financial management, and requisition management functions.

4. SNAP-I

Shipboard Non-tactical Automated Processing System. Shipboard computer hardware system that runs the SUADPS programs (in addition to other application programs such as payroll and personnel administration) on Navy Stock Fund ships.

B. RECEIPT PROCESSING

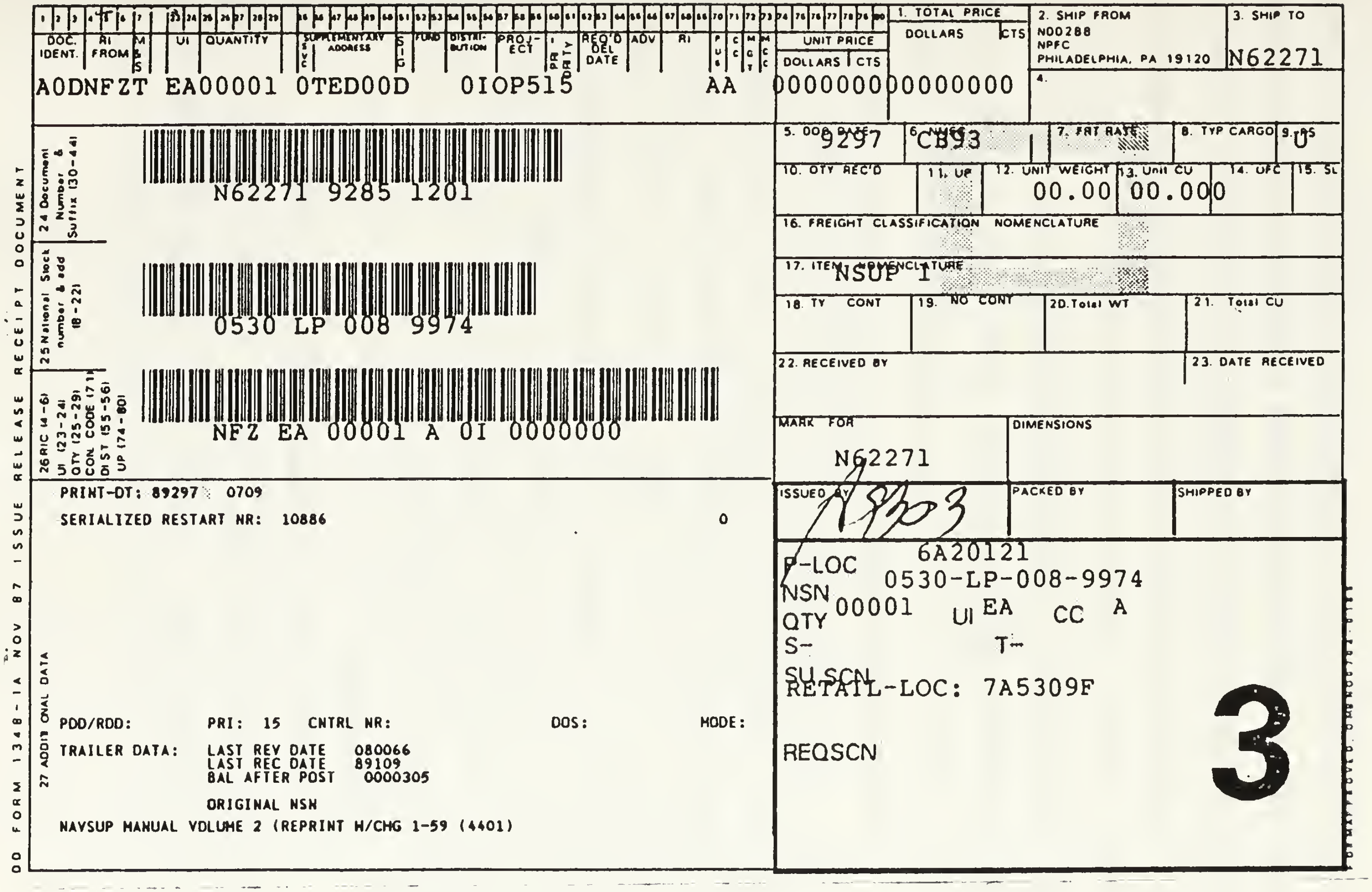
Receipt processing procedures differ slightly between various ship types. Therefore, fleet type commanders (TYCOM) have slightly different receipt processing guidelines their ships must follow. Within the TYCOMs the ships have written receipt processing instructions that vary slightly among ships. The following paragraphs generically describe the receipt processing procedures.

As soon as a shipment of material is received on board ship, receiving personnel divide the material into two groups: stock receipts and DTO receipts. Then the receiving personnel scan the bar coded receipt documents with a portable, battery operated bar code reader (Logistics Applications of Automated Marking and Reading Symbols, or LOGMARS). The device scans the bar coded information and stores it in memory. The stored information includes: requisition number, requisition quantity, national stock number (NSN), unit of issue, unit price, and the routing identifier of the shipping point.

Figure 2-1 shows a copy of a bar coded receipt document. The receipt data from the bar code reader is entered electronically into a microcomputer soon after the scanning process is completed. Those receipt documents that do not have bar coded data are taken directly to the SNAP-I computer for input via the keyboard. The remaining procedures differ, depending upon whether the material is received for stock or for direct turnover to a customer.

1. Stock Receipts

Stock receipts are posted to an outstanding receipt-in-process (RIP) file to show that the material has been received on board, but has not yet been placed in its storeroom location. After the document scanning process is finished, all material received for stock is sent to the appropriate storeroom. For each requisition, the storeroom storekeeper verifies the count, puts the material on the shelf, and records (again) the receipt information by re-scanning the receipt document and scanning the bar coded storage location on the shelf. If the actual quantity received differs from the quantity printed on the receipt document, the storekeeper keys the actual quantity received into the barcode reader via an attached keyboard. The storekeeper annotates the receipt document with the actual quantity received and the storage location, and then he signs the document.



1. TOTAL PRICE DOLLARS CTS
2. SHIP FROM N00288 NPFC PHILADELPHIA, PA 19120
3. SHIP TO N62271
4.

DOC. IDENT. | RI FROM | M&S | UI | QUANTITY | SUPPLEMENTARY ADDRESS | SIG | FUND | DISTRIBUTION | PROJECT | PRIORITY | REQ'D DEL DATE | ADV | RI | PUB | CC | MGT | MC | UNIT PRICE DOLLARS CTS

A0DNFZT EA00001 0TED00D 0IOP515 AA 0000000000000000

24 Document Number & Suffix (30-44)

N62271 9285 1201

25 National Stock number & add (8-22)

0530 LP 008 9974

26 RIC (4-6)
UI (23-24)
QTY (25-29)
CON. CODE (71)
DIST (55-56)
UP (74-80)

NFZ EA 00001 A 0I 0000000

5. DOC DATE 9297
6. NMFC CB93
7. FRT RATE
8. TYP CARGO
9. PS U
10. QTY REC'D
11. UP
12. UNIT WEIGHT 00.00
13. Unit CU 00.000
14. UFC
15. SL
16. FREIGHT CLASSIFICATION NOMENCLATURE
17. ITEM NOMENCLATURE NSUP 1
18. TY CONT
19. NO CONT
20. Total WT
21. Total CU
22. RECEIVED BY
23. DATE RECEIVED
MARK FOR N62271
DIMENSIONS
ISSUED BY
PACKED BY
SHIPPED BY

PRINT-DT: 89297 0709
SERIALIZED RESTART NR: 10886 0

27 ADDITIONAL DATA

PDD/RDD: PRI: 15 CNTRL NR: DOS: MODE:
TRAILER DATA: LAST REV DATE 080066
LAST REC DATE 89109
BAL AFTER POST 0000305
ORIGINAL NSN
NAVSUP MANUAL VOLUME 2 (REPRINT W/CHG 1-59 (4401)

P-LOC 6A20121
NSN 0530-LP-008-9974
QTY 00001 UI EA CC A
S- T-
SU SCN
RETAIL-LOC: 7A5309F
REQSCN
3

DD FORM 1348-1A NOV 87 ISSUE RELEASE RECEIPT DOCUMENT

Figure 2-1. Bar Coded Receipt Document

Source: DD FORM 1348-1A

The actual quantity received often does not match the actual quantity shipped. Therefore it is very important that the storekeeper mark the actual quantity received on the receipt document. If in the future the computer's on-hand inventory figure for a particular NSN differs from the actual on-hand quantity, then the historical documents (marked with actual received quantity) can be retrieved to see if any incorrect receipt quantities were input to the computer at the time of receipt. If incorrect transactions are found, they can be reversed and re-input with the correct receipt quantity, and thus correct the computer's on-hand figure.

The receipt stowage data in the barcode reader memory includes the verified quantity and storage location. This requisition information is placed in the microcomputer and matched against the information in the RIP file. Any matched records are moved from the RIP file to the completed requisition file, leaving only outstanding requisitions that still need stowage information. After the information is input to the computer, the documents are sent to the stock control office to be manually filed.

2. DTO Receipts

The DTO receipt information is immediately posted to a completed requisition file, which is later input to SUADPS records via floppy disk. No RIP file is used for DTO receipts because no inventory records are maintained in SUADPS for DTO material.

After scanning the DTO receipt documents, the material, with receipt documentation attached, is placed in a customer staging area. When the customers pick up their material, they sign the receipt documents as proof of receipt. The documents are then forwarded to the stock control office for filing.

It is extremely important to record the receipt information *as soon as* the items reach the ship. Otherwise material accountability is reduced.

C. ISSUE PROCESSING FROM STOCK

Shipboard divisions send material requirements to the supply department via computer terminals located in their work areas throughout the ship. Requisitions for material not carried aboard ship are sent off the ship via message to the supporting Navy Supply Center (NSC) or inventory control point (ICP). For material that is carried aboard ship, the SNAP-I computer produces a picking ticket denoting the requisition number, NSN, stock location, and quantity requested by the customer. Figure 2-2 shows a copy of a picking ticket. The picking ticket is sent to the appropriate storeroom where the storekeeper retrieves the material. If the material is in stock, he circles the requested quantity and signs the picking

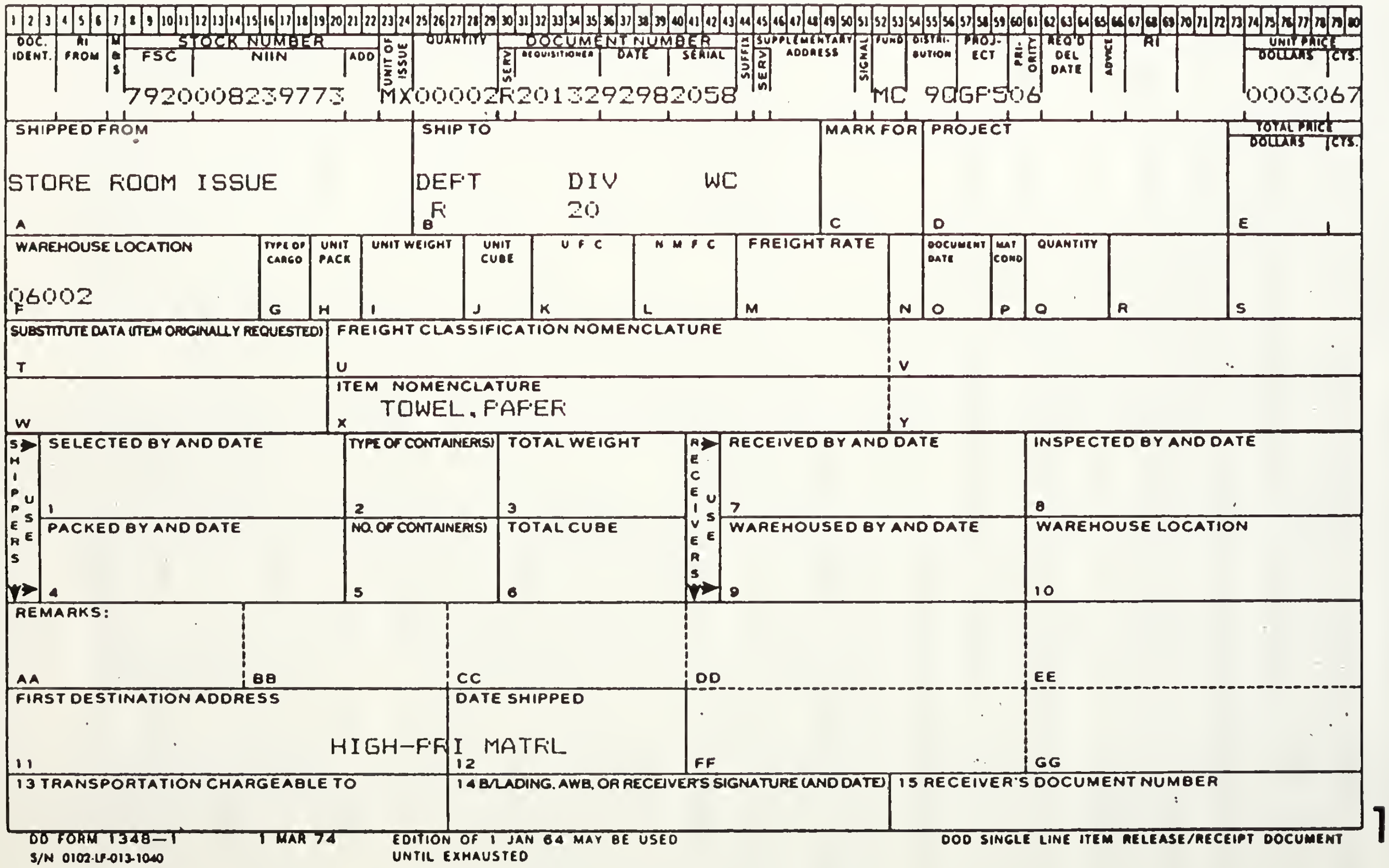


Figure 2-2. Shipboard Issue Document

Source: DD FORM 1348-1A

ticket. If the on-hand quantity can only partially fill the requisition, the storekeeper lines through the requested quantity and marks the picking ticket with the quantity issued. He then sends the material, with the picking ticket attached, to the customer staging area. If no material is in stock, the storekeeper writes NIS (not in stock) on the picking ticket and sends it to the material division office or the stock control office for input to the computer.

When the customer picks up his material from the staging area, he signs the picking ticket as proof of receipt. The document is then sent to the material division office or the stock control office for input to the computer. Since SNAP-I generated picking tickets are not bar coded, all issue information is entered via the SNAP-I computer terminal. The issue documents (picking tickets) are then sent to the stock control office for filing.

Often the quantity issued is not the same as the quantity requested. Therefore it is very important that the storeroom storekeeper mark the actual quantity issued on the issue document. If in the future the computer's on-hand inventory figure for a particular NSN differs from the actual on-hand quantity, then the historical documents (marked with actual issued quantity) can be retrieved to see if any incorrect issue quantities were input to the computer at the time of issue. If incorrect transactions are found, they can be reversed and re-input with the correct issue quantity, and thus correct the computer's on-hand figure.

D. FILING PROCESS

Stock and DTO receipts must be retained aboard ship for three fiscal years. This is necessary to keep the audit trail intact for the reconciliation process, and to show proof of receipt by the customer when the need arises. Filing these receipt and issue documents is a long and tedious process. First the storekeepers must sort the documents by requisition number (which consists of the unit identification code (UIC), julian date, and serial number). (On submarine tenders, they must first sort by the tender's or supported submarine's UIC. All ships must sort by the requisition julian date, and then by the serial number within julian date.) Each document must then be placed in the filing cabinet in the proper requisition number sequence among the documents already filed.

The filing process is time consuming, monotonous, and typically one of the lower priority jobs in the stock control division. Filing is also one of the first tasks dropped when an extra sailor is needed for one of the frequent, unforeseen tasks that must be done immediately. Therefore, the documents literally pile up by the thousands, waiting to be filed. This contributes to lost documents, either through placement in the trash, or misfiling in the cabinets.

The filing cabinets used to store three fiscal years of receipt and issue documents take up much space--a very scarce commodity on board any ship. These cabinets compete with sailors who want space for a desk to do their work.

E. RECONCILIATION PROCEDURES

Various procedures are used to maintain accurate inventory and financial records. No matter how well defined the procedures are, people make mistakes in processing issues and receipts. Therefore, the supply system has developed several reports and reconciliation procedures to identify and correct the mistakes that sailors make in daily transaction processing. The reconciliation measures described below contain a basic overview of the required actions, with an emphasis on how receipt and issue documents are used to help correct the discrepancies.

1. SUADPS Error, Suspended, and Information List Processing

The error, suspended, and information listings detect discrepancies soon after transactions are entered in the computer. The Transaction Error Listing contains transactions that the computer rejected due to erroneous format or data fields.[1] The Suspended Transaction Listing contains records which are correct in format but are unable to process due to

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[1] Currently Navy Stock Fund ships are shifting from SUADPS version 2 to version 3. For ships with version 3, error processing does not apply. Version 3 is a real time program that immediately verifies data fields during key entry, and requires the operator to re-enter the data in the correct format.

a SUADPS file condition. The Information Transaction Listing contains records which have processed, but either require further action, or indicate a possible input error that passed all format or file conditions. SUADPS will assign a Message Key Number (MKNR)[2] and either reject or suspend the transaction, depending on the discrepancy type. The primary difference between suspended and rejected transactions is that SUADPS automatically tries to reprocess the suspended record during the next 15 updates before it is rejected on the error listing.

One example of a rejected transaction is a receipt on which the unit of issue on the item received does not match the unit of issue in the master record file. An example of a suspended transaction is an issue on which the released quantity in the transaction is greater than the on hand quantity in the stock record. A common example of a transaction that SUADPS puts on the information listing is when an extended money value on a transaction exceeds a predetermined amount established by the stock control officer.

In each case, the first step to research the discrepancy is to retrieve the receipt or issue document to see if the correct unit of issue, actual issued quantity, or unit price was entered into the computer. In many cases the

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[2] A MKNR is a code that is used to tell why SUADPS rejected or suspended the transaction, or placed it on the information listing.

discrepancy can be corrected by re-entering the correct data from the document.

2. C&H and A&G List Processing

Every month the ship sends a listing of all receipt transactions to the Fleet Accounting and Disbursing Center (FAADC). These receipts are matched up with billing reports that are sent to FAADC from the stock points that shipped the material to the ship. The Unmatched Listing For Captions C and H (C&H Listing) contains all unmatched expenditures for which the shipping point sent the bill, but the ship did not report receipt of the material. The Unmatched Listing For Captions A and G (A&G Listing) contains all unmatched expenditures for which the ship reported receipt, but the shipping point did not send the bill. Both listings contain requisitions where the ship's and shipping point's extended money values do not agree.

The most common reasons for a transaction to end up on the C&H listing are: (1) the ship actually received the material, but the transaction was never input to the computer, or (2) the receipt was input with the wrong unit price. To correct these discrepancies shipboard personnel search the material completed file for the receipt documents and re-enter the correct receipt information into the computer.

The most common reasons for receipts to appear on the A&G listing are:

1. Receipts may have been processed correctly but no bill has been submitted by the issuing activity.

2. The ship may have erroneously processed the receipt twice.

3. The ship may have processed the receipt twice reflecting a duplicate shipment and the second bill has not yet been submitted by the issuing activity.

To research A&G discrepancies, shipboard personnel must first check the material completed file to determine if the material was actually received. Most documents appearing on the A&G list will be valid [Ref. 5]. If these records have been on the listing for more than 6 months, the ship should submit a form to the shipping activity requesting that they bill the ship for the material. A copy of the receipt document should be furnished as proof of delivery.

3. Outstanding Requisition File Maintenance

Ships must continually review their outstanding requisition files to make sure they only contain valid outstanding requisitions in the supply system. This is especially crucial when repair parts are involved that the ship needs to perform its mission. A part will never reach the ship unless the requisition is alive in the supply system.

The ship's type commander closely monitors the number of requisitions on file with overaged shipping status. Often the material has been received, but the SUADPS records have not been updated. The first place to look is the material completed file to determine if the receipt document is there. If it is, the receipt is processed and the requisition is completed in SUADPS.

4. Inventory Reconciliation

Inventory accuracy has always been a highly visible issue on all Navy ships. During supply management inspections, the TYCOMs closely review inventory records, comparing record quantities with actual on hand quantities in the storeroom. To monitor inventory accuracy, physical inventories are conducted on a daily basis aboard ship. For instance, many times an attempt to issue a repair part results in a "storeroom refusal" (no part on hand) even though the computer indicates a quantity on hand. SUADPS prints a daily storeroom refusal report, and the supply department's Quality Assurance (QA) personnel conduct a physical inventory of the NSN. If no parts are found, or the computer indicated quantity is not found, the QA people must try to find out why. Research begins by reviewing the issue and receipt documents.

Wall to wall inventories are extremely difficult, time consuming, and expensive to do. They are typically conducted during extended periods when the ship is restricted to port, such as shipyard overhaul periods. Physical inventories are conducted despite the high cost because the ship must be repaired when damaged, and the parts must be on board to do the repair.

The wall to wall inventory process begins well before any physical inventories are conducted. In order to reduce potential inventory adjustments in both the long and short term, SUADPS inventory and financial files must be corrected. This file correction is very important. If discrepancies on the ship's C&H, A&G, error listing, suspended listing, and outstanding requisition files still exist after actual inventory reconciliation commences, many discrepancies will undoubtedly remain at reconciliation completion. These unresolved discrepancies represent possible inventory adjustments that should be made prior to physically counting items in the storerooms.

After file correction is complete, the physical inventory commences. Any NSN's with physical counts that do not match SUADPS on hand values must be researched. Issue and receipt documents are the first place the researcher looks to see if an input error was made. Reversing input errors prevents having to make undesirable inventory adjustments.

F. NEED FOR ISSUE AND RECEIPT DOCUMENTS

The preceding paragraphs have emphasized the need to accurately enter information into the inventory and financial database *at the source* -- by correctly entering the data from issue and receipt documents. Both of these transactions directly affect the ship's inventory and financial record accuracy. Yet people make mistakes. To correct the mistakes, the only way to determine what information should have been recorded is to check the source documents. Therefore, it is imperative that the ship maintain a document file system that not only allows for fast, accurate filing, but also enables the ship's personnel to quickly and easily retrieve the documents when needed. Unfortunately, receipt and issue documents are often filed without entering the transactions to the computer, or they are misfiled or lost.

The ship's divisions often claim they did not receive their requisitioned material, but the SUADPS records show they did receive it. This is another reason why we need to store the issue and receipt documents -- they contain the customer's signature as proof of received material. When the documents are on hand, they prevent arguments and reinforce the supply department's reputation for good service. When the documents are not on hand, the supply department looks bad.

G. FUNCTIONAL DESCRIPTION FOR NEW SYSTEM

As mentioned earlier, the current manual document filing system is bulky, time consuming, and error prone. Due to recent advances in document storage technology, many alternatives exist to the manual filing of source documents.

But before we investigate any specific alternatives, we need to identify the functional elements that must be included in the new document storage and retrieval system.

1. Store All Issue and Receipt Documents

The system must store all issue and receipt documents (Figures 2-1 and 2-2) or their exact images.

2. Quick Document Filing and Retrieval

To overcome today's continual filing backlog, the new system should speed-up the filing process so that it only takes two to three man hours per day or less, to file all documents.

3. High File Accuracy

On average, twenty eight percent of the documents we tried to retrieve from actual manual files aboard ship could not be located.[3] The documents were either lost or misfiled. The new system must substantially reduce the misfiling rate, preferably to near zero percent.

4. Small Space Requirement

The current paper files occupy 205 square feet of deck space. The new file system should only occupy the space required by an average size desk (30" X 60") or less.

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[3] See time and motion analysis results, Appendix B

5. Retrieval by Requisition Number or NSN

The system should enable a sailor to retrieve a document by requisition number for financial reconciliation or NSN for inventory reconciliation.

6. High Storage Capacity

The system must be able to store three fiscal years worth of issue and receipt documents. For an aircraft carrier, this means a three year file capacity of about 491,250 documents, each 5.5" X 8.5 " in size.

7. Daily Processing Capability

The system must allow a sailor to file and retrieve documents on a daily basis.

8. Image Reproduction

The system must be able to produce a paper copy of the document for users for submission to customers as proof of delivery, or to aid in the inventory and financial reconciliation process.

H. FILING AND RETRIEVING ALTERNATIVES

This section lists several technological alternatives that can perform some or all of the functions listed in the previous section. Although many combinations of the following technologies could be integrated to form a feasible document storage and retrieval system, the technologies are basically taken from three categories: a manual filing system (current system), a microfilm or microfiche system, and a Personal Computer based document image filing and retrieval system.

1. **Physical Handling of Documents.**
   a. Human hands
   b. Combination of automatic document feeder and human hands

2. **Document or Image Storage**
   a. File cabinets
   b. Optical disk
   c. Magnetic disk
   d. Microfilm
   e. Microfiche

3. **Document Indexing**
   a. Physical file location in file cabinet in requisition number *or* NSN sequence
   b. Optical disk index
   c. Magnetic disk index
   d. Paper index

4. **Document Retrieval**
   a. Human hand search in file cabinet
   b. Computer search using index on magnetic or optical disk
   c. Human search of paper index and retrieval of microfilm or microfiche

5. **Retrieve Information From Document**
   a. Read original document
   b. Read image on computer monitor
   c. Read image on microfilm or microfiche reader
   d. Read document on paper copy of image

6. **Document or Image Reproduction**
   a. Copy machine
   b. Dot matrix printer
   c. Laser printer
   d. Microfilm or microfiche reader printer

The above lists of alternatives do not necessarily cover all possible technological alternatives. However, we feel the lists cover the range of currently available and relatively inexpensive alternatives that the Navy might use to store issue and receipt documents. The current manual filing system is among these lists of alternatives.

The next two chapters discuss the alternative technologies to manual document filing.

III. EMERGING TECHNOLOGIES IN DOCUMENT IMAGING

This chapter discusses in detail the various types of imaging systems available today. The functions, characteristics, advantages, and disadvantages of each system and its related components are also presented.

A. MICROFILM TECHNOLOGY

The storage and retrieval of images is not new. Earlier in this century, businesses recognized the paper problem. For legal reasons, some paper files could not be destroyed. They are required to support the payment of invoices, customer inquiries, inventory balances, and many other requirements. And as a matter of convenience, they could not be stored off-site because of the massive efforts to reproduce file duplicates.

As early as 1929, business turned to microfilm for records management. The process is relatively tedious. Images are captured by a camera, recorded on roll film or fiche and stored in cabinets. In this way, microfilm records can be stored in much less space than paper files. Card catalogs reveal the location of a particular image, the user mounts the whole roll in a microfilm reader, and then manually scans to the needed frame.

Two types of cameras are commonly used to capture microfilm images:

1. **Rotary Camera**

Rotary cameras synchronize the movement of documents and film past the lens. Automated paper handling allows an experienced operator to feed the rotary camera up to 1,000 documents per hour. Both sides of the document can be filmed at once. Attached to a personal computer (PC), newer models simultaneously get indexing information like document number, voucher number, etc., and the starting/ending frame numbers for each document. The index data can also be endorsed or printed on the source document. During filming, a rectangular mark called a "blip" is placed above or below each frame so that an automated retrieval device can later locate selected images. Documents to be filmed may be in any order, but the indexing information must be entered during the filming process.

2. **Planetary Camera**

Planetary cameras photograph stationary documents from an overhead position. Mounted over a rectangular table, the planetary camera head can be moved up and down to accommodate documents up to 11" X 17" size. The planetary camera can be attached to microcomputers to record information needed to build the database. The index data can also be recorded on the source document.

When volume is high and turnaround time is tight, most users choose to process microfilm on site. Most non-commercial film processors will work in the office environment, although some require fresh water plumbing. A dark room is also required where the film can be removed from the camera without exposure to light. To check on quality, microfilm must be inspected immediately after processing particularly if the source documents are to be destroyed. Inspection can also uncover problems with the camera, film operations, or film processing. If found defective, images can be refilmed and spliced into the original roll.

Processed films are mounted on round cartridges which can be easily mounted on reader-printers. Manual index and retrieval of images is slow and cumbersome. It is only marginally better than the paper-based files it replaces. A Computer Aided Retrieval (CAR) system adds basic computer automation to the process. CAR systems consist of three components: the microfilm reader, microfilm cartridges for storing the image database, and a PC or minicomputer with an index database. The database management system indicates which cartridges to load into the reader, and then automatically searches for the selected image once the cartridge is loaded. If the PC is not connected to the reader, the user must search for the image number manually to locate the document image. Some microfilm readers can produce a same-size hard copy of the screen image. The paper image from these reader-printers is similar to those from inexpensive copiers.

Thousands of companies, including the Department of Defense, have chosen microfilm technologies to store information. A summary of advantages follows:

1. Saves space. Information stored on microfilm consumes only 3 to 10 percent of the space required on paper-based files [Ref. 6].

2. Security. Only duplicate copies circulate. The original is stored in a secure location. Copies are inexpensive to make, and can be mailed for a fraction of the cost of an equivalent amount of paper.

3. Legality. For many years, microfilm has been a legally acceptable medium for evidentiary purposes.

4. Longevity. Properly processed and stored, microfilm will last for over 50 years [Ref. 6].

5. Ease of use. Microfilm readers demand no lengthy training, and are easy to use. CAR systems simplify data retrieval from large databases. And reader-printers produce a copy of the image at the push of a button.

6. Uniformity. Documents in multiple sizes can cause storage problems. Microfilm however, reduces them to uniform size, and stores them on a roll of film.

Although it has been a popular choice since 1928, microfilm is now being replaced by electronic imaging technology. There are several reasons for the change. First, microfilm is a time consuming process, involving film and camera preparation, photography, and film processing. It is not instant imaging. It is not a real-time process. As a result, documents are not available for viewing until after the film has been processed and developed. If immediate action is required to view documents, the actual paper copies must be distributed rather than images. In such an instance, the benefits of microfilm technology are significantly diminished. Finally, the film, chemical developers, reader-printer toner, and paper, have "shelf-lives" and must be used before their expiration dates. They also require special handling and storage. In contrast, electronic imaging allows images of documents to be viewed immediately after capture. Immediately upon being scanned into the system, they become part of a database. This expediency permits tighter quality control.

B. ELECTRONIC DOCUMENT IMAGING TECHNOLOGY

Document imaging has matured from basic filing capability to a mainstream information system capable of integrating several individual technologies:

1. a database that provides a flexible means of indexing image documents for later retrieval,
2. mass storage devices for maintaining the voluminous image files,
3. laser scanners with microprocessors that compress images for mass storage, and decompress the same images for viewing and printing,
4. high resolution monitors for viewing the documents on workstations,
5. distribution systems for sending and printing images.

Each component of a core system can take many different forms, depending primarily on the application. The imaging system may include one or more optical scanners. The number of optical disk drives may be increased depending on storage requirements. An electronic imaging system may be a stand-alone system or operate in a network with various workstations in a single facility or in remote locations. Each component of an electronic document imaging system is described below.

1. Optical Scanners

In any type of imaging system, the image must first be "captured". Once captured, the unaltered copy of the image or document is stored permanently in the storage device. An optical scanner is the device used for capturing document images for storage on optical or magnetic disk. Although the scanner looks and functions like a paper copier, it produces an electronic, digitized copy of a document.

All document scanners, from desk top units to top of the line systems capable of scanning both sides of a document at once, share one common characteristic, they start by creating a bit-mapped digital image of the source document. In some applications, all that is needed is an image with a simple retrieval tag and display software.

For most scanners, the host system controls the image area being scanned. With the use of recognition devices, storage and retrieval systems can bring full resolution of the scanner array to bear on documents of various sizes.

The simplest and most economical use of scanner output is a full page image because it is fast and relatively cheap to capture. The user sees exactly what was on the original page. The image is reusable, and can be reproduced.

The most popular and widely used scanner in document imaging is a "laser image scanner". This scanner uses a rotating laser beam which scans image elements at resolutions close to a few ten-millionths of an inch [Ref. 7]. The low power beam's reflector produces a raster-scanned or bit-mapped video signal in a photoreceptor device.

Current scanning technology of images centers on two basic methods: raster scan (bit mapped), or vector scan (line mapped). Both methods start with a hardcopy image, and both produce digital encoding for storage and manipulation by a computer.

a. *Raster Scanning*

This technology was first used in interactive computer displays in the early 1970s. It has now become a dominant technology in optical imaging, especially for low cost microcomputers. Unlike vector images which must be entered into the computer with time-consuming help from a skilled Computer Aided Design (CAD) operator, raster images can be entered into a computer in seconds by an optical digital scanner. Once the scanner reads an existing paper or drawing, the raster image can be immediately presented and edited on a graphic display.

Raster scanning treats an image or document as a rectangular array of points called picture elements or pixels or pels. The reflectivity of each pixel is sampled during the scanning process to produce an array in which each value characterizes the grey-scale (monochrome scanning) or color intensity (color scanning) of the corresponding focal point on the page. A variety of techniques can be applied to the raster to enhance image quality, recognize samples, compress the image, or isolate portions of interest.

Raster scanning converts the raw input data to a more useful form. This form ranges from a simple bit array, in which each pixel is characterized as either black or white, to an array of grey scale values, in which each pixel is characterized as having one of several (e.g., 6, 8, 12) shades of grey, to a full color raster, which characterizes each pixel in terms of its intensity of three primary colors.

Raster scanners typically perform four functions: 1) image detection, the conversion of an image to an electronic form; 2) thresholding, the determination of relative black and white values, the lowest grey level for which a pixel will be recognized as having a value; 3) image enhancement, the removal of extraneous marks, and other manipulations; and 4) compression, the compacting of raster data to reduce the amount of storage required to represent an array of data.

There are many variations of raster scanning products, different photodetection technologies, different document handling systems, and different interfaces, but the principle remains the same. When the scan is complete, the raster data is stored. Subsequently, the image can be edited or reproduced by the same method working in reverse, using a plotter or laser printer.

Raster scanning has a number of distinct advantages and disadvantages. Because each pixel must be measured, the method uses up a great deal of storage. A typewritten page with 2,000 characters would take up 2 kilobytes (KB) if converted to American Standard Code for Information Interchange (ASCII) code by an Optical Character Recognition (OCR) device. If raster scanned at 200 dots per inch (DPI), the same page would require 470KB as a monochrome bit raster, and several megabytes for a full color raster before data compression to cleanly reproduce the page. Some flexibility is permitted in the choice of resolution or number of pixels designated, but once the selection is made, the raster scan technique requires all the picture elements to be read. There is a trade-off and, therefore, a value decision involved. As Figure 3-1 indicates, there is a direct effect on image

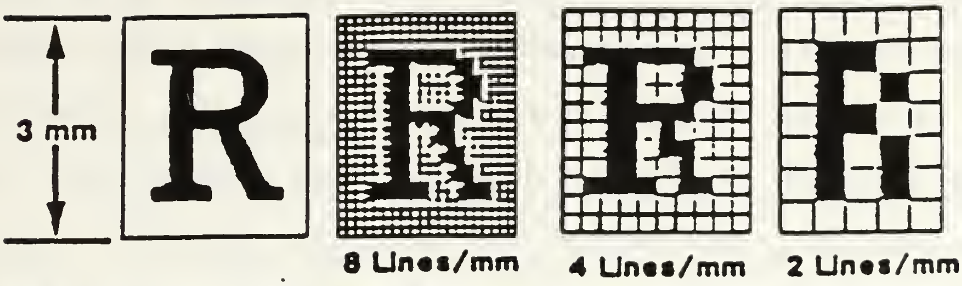


Figure 3-1. The Effect of Density of Pixels on Readability
Source: Association for Information and Image Management, Silver Spring, Maryland, 1987.

quality in relation to the resolution or density of scanning selected. Figure 3-2 shows the number of bits of storage space required for different size drawings scanned at 200 DPI with no margins. Of course, as the resolution increases, so do the storage requirements. Despite the large storage requirements for grey tones, such as in photographs, raster scanning is the only means of converting photographic analog data to machine-readable code. [Ref. 8]

Size Designator	Image Size Inches	Image Size mm	# of Bits Before Data Compression
A	8.5 × 11	215.9 × 279.4	3,740,000
B	11 × 17	279.4 × 431.8	7,480,000
C	17 × 22	431.8 × 558.8	14,960,000
D	22 × 34	558.8 × 863.6	29,920,000
E	34 × 44	863.6 × 1117.6	59,840,000

Figure 3-2. Bits of Storage Required for Different Size Drawings at 200 dpi with no Margins
Source: Association for Information and Image Management, Silver Spring, Maryland, 1987.

Resolution, or quality of the captured image, is an important issue with raster scanners. For the user, the important issue is one of subjectivity, aesthetics, or functionality. The tradeoffs for increased image quality are the increased storage requirements and cost. Image quality is a function of storage density. The greater the number of dots per inch, the better the resolution or image quality. If the number of dots per inch are doubled, the storage and processing requirements are quadrupled. As indicated in Figure 3-3, any increase in the number of points in the image array dramatically increases the number of bits required to store the more enhanced image. [Ref. 9]

"N" \ "M"	1	2	3	4	5	6	7	8
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,388
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152

"N" = array of imaging points
"M" = number of bits required

Figure 3-3. Image Quality as a Function of Storage Density
Source: Association for Information and Image Management, Silver Spring, Maryland, 1987.

Resolution, therefore, becomes better as storage capacities increase and as the price of the system increases. Also, higher resolution requires higher processing power to perform a function in the same amount of time.

Finally, raster scanning is the image industry's preferred choice for reproducing images of original documents or as input to further image processing steps or software [Ref. 10].

b. Vector Scanning

Images in CAD systems are constructed using vector technology. A vector device draws figures line by line. A CAD operator constructs each image as a series of lines and arcs, and other graphic elements, using vector data. These data consist of geometrical definitions of each graphic element and symbol, as well as interrelationships between them. As shown in Figure 3-4, precision is sometimes required for engineering designs and drawings.

In a vector display, each line is redisplayed each time the display is updated - usually thirty times per second. Therefore, changes to the data can appear within 1/30th of a second. Vector scanning is good for CAD and other engineering systems where further manipulation or integration of data is needed and precise measurements/dimensions are required.

2. Image Compression/Expansion Processor (CEP) Board

Until recently, there were always two impediments to converting information stored on paper to a bit-mapped format. One was lack of image memory. Even if images were digitized and compressed, few storage devices could contain enough images to make the effort worthwhile. On average, a typical 8.5" X 11" document scanned at 300 pixels per inch (PPI) takes 1 megabyte (MB) of storage. Compressed at 15:1 ratio, 150

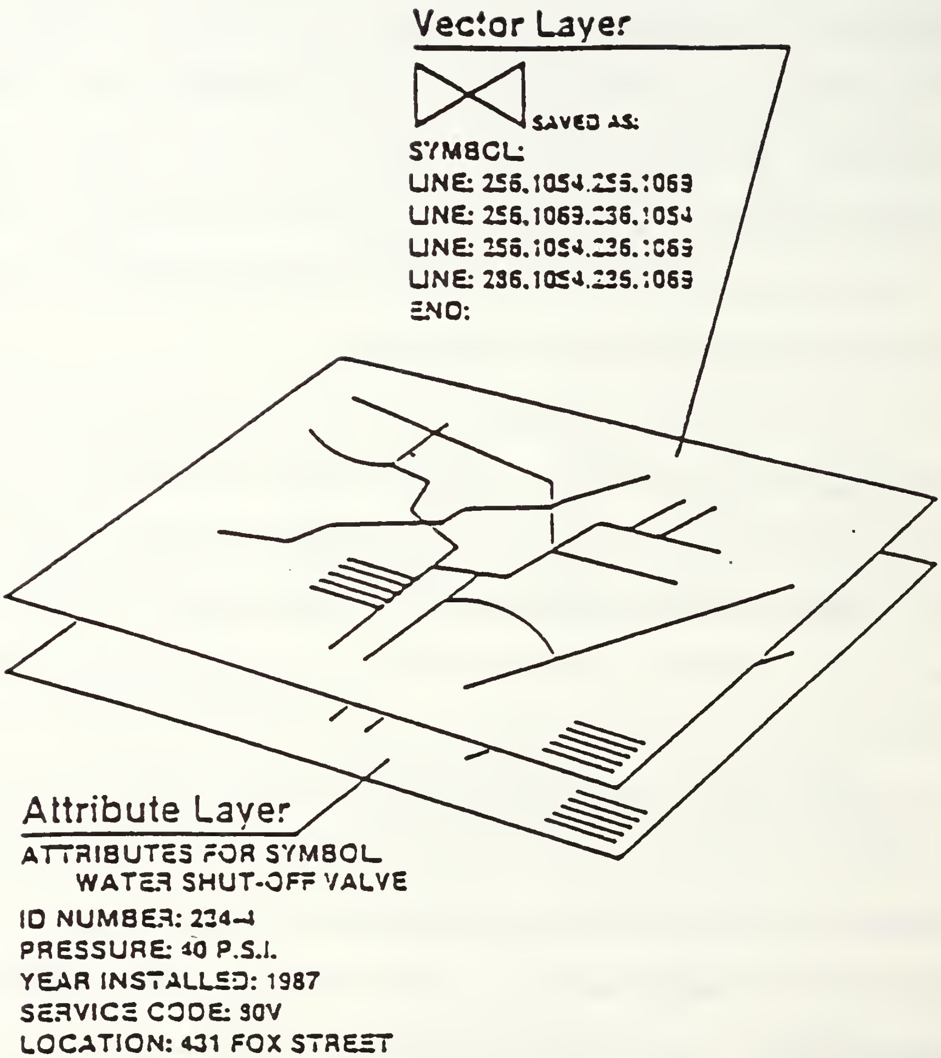


Figure 3-4. Vector Technology

Source: INFORM, May 1988.

such documents would fit in a 10 MB hard drive. Today, mass optical storage devices make it possible to store much larger volumes of scanned documents in electronic form.

The other problem was the excessive time required for image retrieval. Until compression/expansion microprocessors became available, image compression and expansion were performed by software. It took at least 30 seconds for a typical document to go through the compression/decompression process. With CEP boards installed in microcomputers interfacing with optical scanners and disk drives, such operations take only a few seconds.

Most two-tone CEPs are based on the CCITT Group 3 and 4 standards, developed for use in facsimile machine transmission. These standards are based on a combination of two image compression algorithms known as Modified Huffman (MH), and Modified Read (MR) encoding.

Huffman encoding, also known as one-dimensional encoding, works on an image one horizontal line at a time. Each run length, or continuous string, of black or white pixels is given a code based on the probability of that particular length. To achieve image compression, the codes for the most probable run lengths must be shorter than the run lengths themselves. The CCITT Group 3 standard uses the Modified Huffman encoding [Ref. 11].

Modified Read encoding, also known as two-dimensional encoding, takes advantage of the vertical correlation between adjacent lines within a document. It has been estimated that 50% of all transitions from white to black, or vice versa, occur directly below a transition on the previous line. To encode using the "read" algorithm, the relationship between a transition on the current line (coding line) and the previous line (reference line) is determined. If the current line transition is within three pixels of a transition on the previous line, a vertical mode is indicated. This case is represented by a short code indicating vertical mode, and another code indicating the relative distance between the current line transition and the transition above it. If the distance between transitions is more than three pixels, the pixel distance is encoded using the appropriate MH code. This is known as horizontal mode. A third technique, known as passmode, is used to realign the transition pointers between the coding and reference lines.

The CCITT Groups 3 and 4 standards use both MH and MR techniques. The Group 3 standard consists of three options. The first is the one-dimensional Huffman encoding I described above. The other two are a combination of MH and MR encoding. In the combination of MH and MR mode, a given line is encoded using MH technique, and K-1 lines are encoded using MR technique. The Group 3 standard recommends K values of

2 or 4. Since a line coded with MH does not require a correctly decoded reference line above it, all of the Group 3 methods will resynchronize after receiving incorrect compressed data. This makes them more suitable for such noisy environments as telephone lines. Group 4, in contrast, codes the first line using MH, while the remaining lines use the MR algorithm. Any transmission errors in the compressed file will corrupt the remainder of the image.

In designing an image storage and retrieval system, trade-offs between compression and expansion speed as well as image appearance (resolution) must be considered. In most imaging systems, compression speed is more critical than expansion speed since documents typically are retrieved much less than they are stored.

Figures 3-5 and 3-6 show the relationship between expansion/compression speeds and document scan density. These data were compiled from average expansion times for eight CCITT test documents using Hawkeye Image System's AMD 7971 CEP operating at 8 megahertz (MHz) speed [Ref. 12]. As one would expect, Figure 3-5 shows that the expansion speed decreases with higher scan density. The expansion of Group 3 encoded documents is about twice as fast compared to Group 4 documents This is due to the longer algorithm used for decoding Group 4 images. In Figure 3-6, as can be expected, the image files compressed using the Group 3 algorithm are approximately twice as large as those using Group 4.

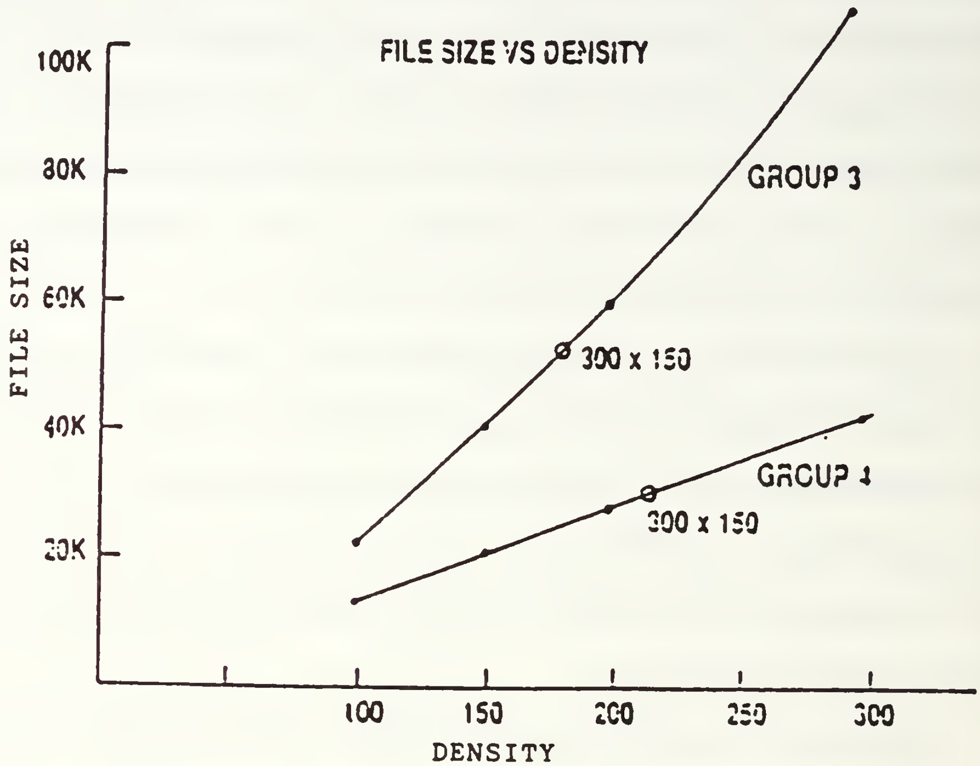


Figure 3-5. Compressed File Size versus Scan Density
Source: ESD: The Electronic System Design, July 1988.

3. Recognition Devices

Until now, paper, microfilm and other information media required expensive operator keyboard entry to input and electronically code data. Linking automated recognition devices with optical and magnetic data storage makes it cost-effective to electronically store and access virtually any

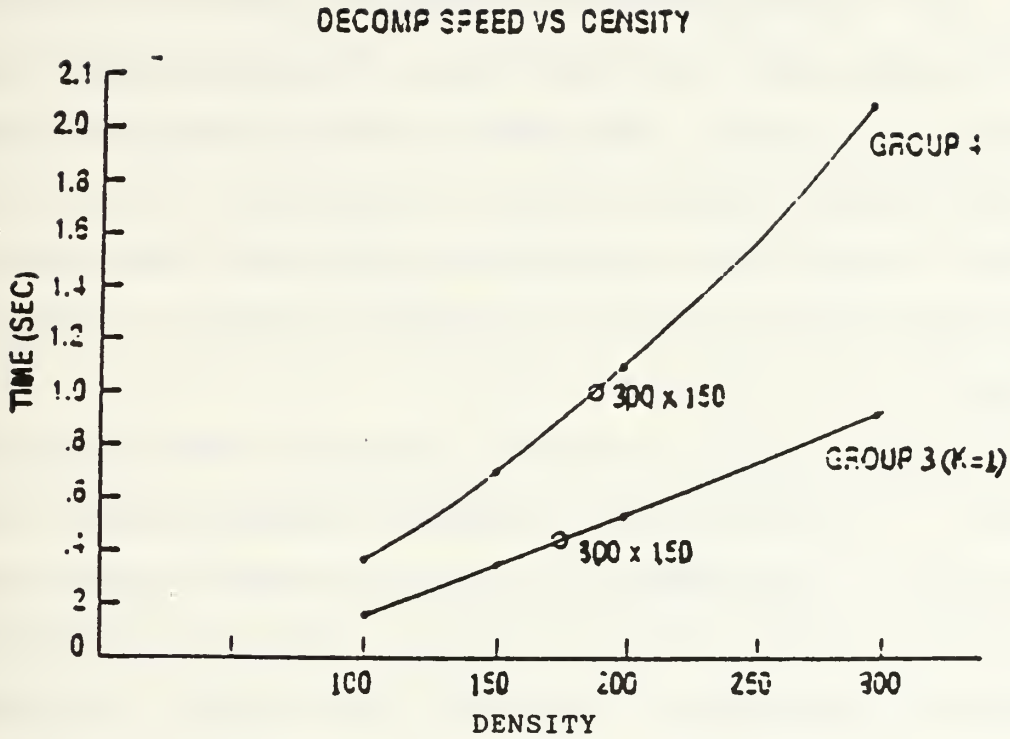


Figure 3-6. Decompression Speed versus Scan Density
8 MHz 7971

Source: ESD: The Electronic System Design, July 1988.

recorded information, greatly increasing overall information management efficiency.

Recognition devices are basically used as a tool which permits the capture of index information directly off the scanned document and automatically enters such information into the appropriate data fields of the indexing database.

Although recognition devices do not entirely replace human keyboard entry, they can replace most of it, and thus reduce the potential for error and speed up document processing input at a rate that can conservatively be estimated at 5 to 1 [Ref. 13]. Furthermore, these technologies are not subject to a fatigue factor and other human characteristics. Much attention has recently been given to the deleterious effects of video display terminals (VDTs) on employees in the private industry. Most of the recognition technologies offer maximum input without having operators stationed in front of computer monitors.

There are two general categories of recognition devices. First is an automatic identification group consisting of Image Character Recognition (ICR), Optical Mark Recognition (OMR), bar code, magnetic stripe, Magnetic Ink Character Recognition (MICR), and radio frequency identification. Second is a personal identification (biometric) group consisting of fingerprint identification, retinal eye scan patterns identification, voice recognition, hand geometry, and signature verification.

The two most widely accepted recognition devices used by private industry and the federal government are OCR and bar code.

a. Optical Character Recognition (OCR)

OCR is the process of converting information from a scanned image into a machine-readable document. Information from a document can be entered into a data record, or used to automatically index the image for storage and retrieval. OCR recognition is good for the recovery of text where further manipulation and indexing is required.

The simplest way of entering text into a machine-readable form which the computer can manipulate is through the use of a computer keyboard. The two industry standards used to convert text into machine readable form are called American Standard Code for Information Interchange (ASCII), and Extended Binary Coded Decimal Interchange Code (EBCDIC). One of the functions of data input devices is to translate information into ASCII or EBCDIC format. When an operator types on a computer keyboard, he or she is translating alphanumeric characters to ASCII or EBCDIC equivalents which lie under each key. Typing the required data into the computer can be a time-consuming process and is subject to operator error. With the use of an OCR device, a typewritten or printed document can be scanned, data stored as bit-mapped images, and then converted into ASCII codes.

The first approach to text recognition was called "matrix matching" or "character-matching". In this method, the computer scans the text character into its memory and then compares the electronic image on a pixel-by-pixel basis with a library of reference standards. Once a character is recognized, it is converted to its electronically codable ASCII equivalent. Matrix-matching works well for documents limited to only a few type faces, point sizes, and document formats.

Confronted by documents containing multiple type faces and point sizes, OCR systems based on character-matching begin to break down. The more complex and varied the document text and format, the more time the OCR system spends in searching for the correct reference standard (See Figure 3-7).

A more advanced OCR device uses a pattern-matching algorithm instead of comparing a scanned letter with an image residing in the computer's memory. This OCR system was developed for the blind by Palantir Corporation of Santa Clara, California. It uses a process called "feature extraction". This recognition device used in Kurzweil desktopscanners is capable of recognizing text characters regardless of typeface or point size variations. This is done by extracting the significant features of a character that gave it a unique identity (Figure 3-8).

Feature extraction method of OCR recognition has some problems. Broken, deformed, or skewed characters in a document are not easily recognized using this technology.

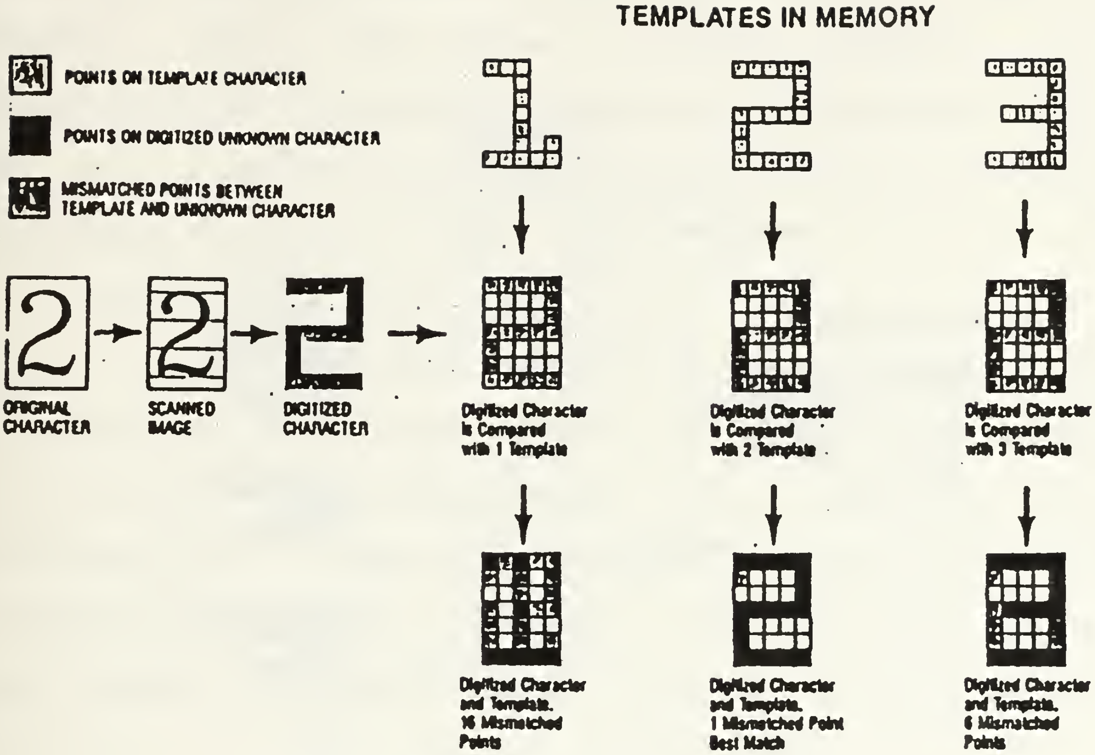


Figure 3-7. Matrix Matching

Source: INFORM, May 1988.

Characters touching one another as well as characters printed across ruled lines are not sharply defined, which degrades system performance.

In developing a robust OCR device, researchers and engineers of Calera Recognition Systems of Santa Clara, California abandoned the search for a single "perfect recognition criterion". Instead, their engineers adopted a hierarchical system of less than perfect prioritized criteria. If a text character can be identified by feature extraction alone, no further recognition processing is required and the

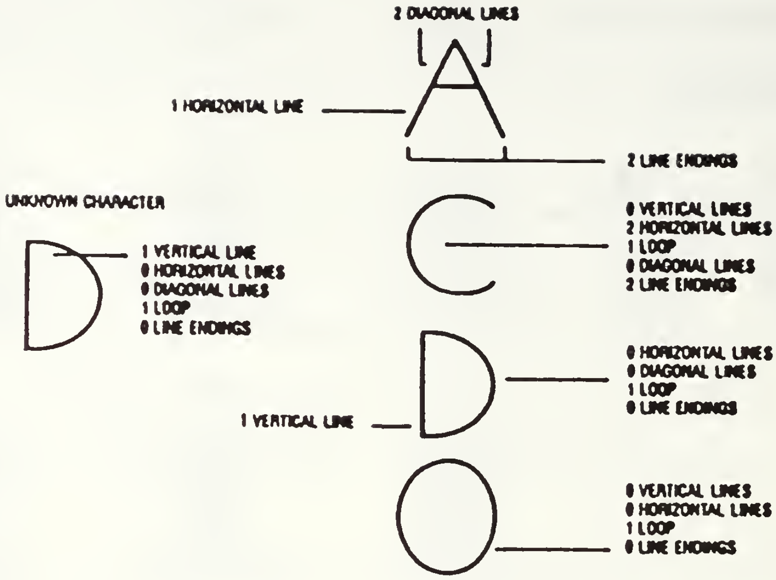


Figure 3-8. Feature Extraction

Source: INFORM, May 1988.

system moves along to the next character. If feature extraction is insufficient for unambiguous identification, the program goes on to examine a character's word placement, spelling relationships, or frequency of appearance. In every case, just enough recognition processing power is brought to bear to achieve the recognition task. This recognition method identifies text errors such as broken, deformed, and skewed characters, characters touching each other, characters printed across ruled lines, as well as other recognition problems caused by format variations or the interleaving of text and graphics. This OCR system is called "Omnifont Text Recognition" or "Intelligent Character Recognition" (ICR), [Ref. 14]. Figure 3-9 shows the omnifont optical character recognition process.

b. Bar Code

A bar code is a printable machine language which reproduces the bit-streams of ones and zeros which are the basis for the internal logic of all digital computers. When organized into a particular pattern, these bit-streams represent an alphanumeric character which can be read by bar code scanners and communicated directly to a computer. [Ref. 15]

These ciphers or bytes are constructed from a series of dark and light bars organized into various patterns which represent letters, numerals, and other human-readable symbols. While there are many different bar code formats, the major difference between them is the relative position and width of the dark and light bars and the number of elements used to symbolize a character. Figure 3-10 illustrates the character structure of a typical bar code. The symbol illustrated is Code 39 (3 of 9) for the character "6".

What does barcoding have to do with a document storage and retrieval system? The key to such a system is the index, or inventory of all documents stored, and that

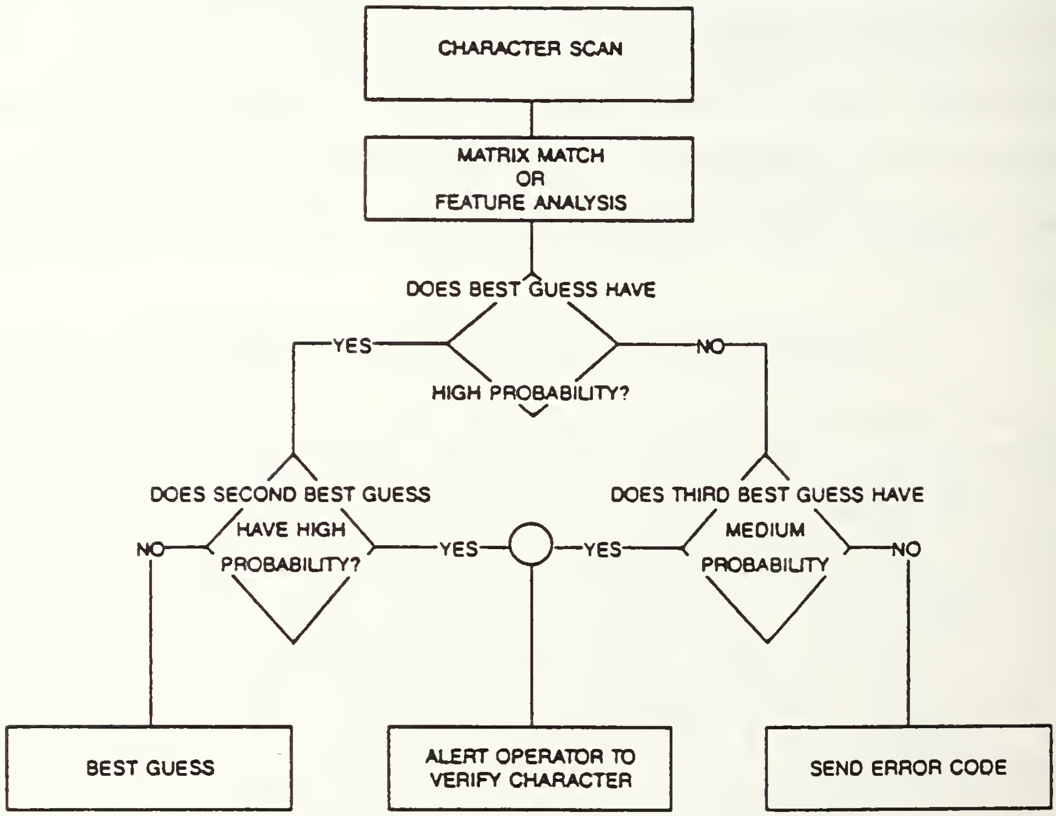


Figure 3-9. Optical Character Recognition Process

Source: Association for Information and Image Management, Silver Spring, Maryland, 1988.

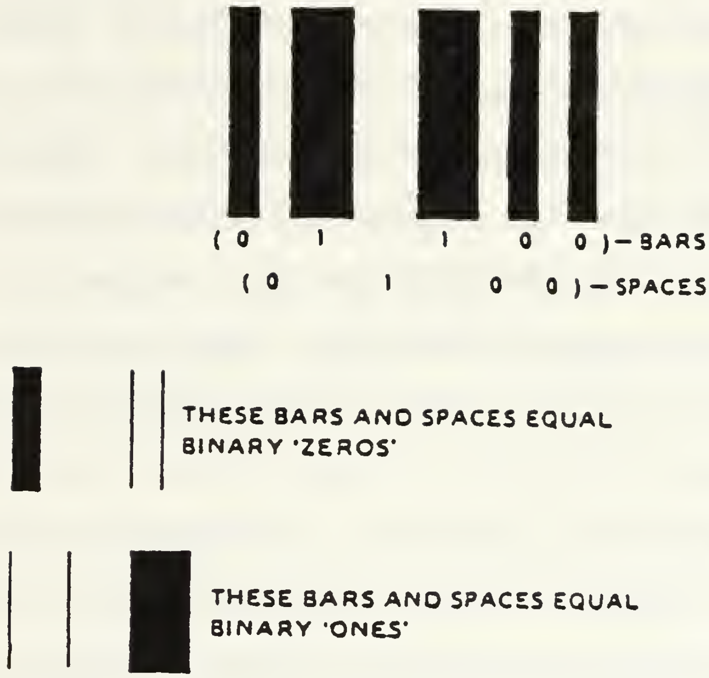


Figure 3-10. Bar Code Character Structure
Source: MSI Data Corporation, September, 1981.

indexing requires data entry. If indexing information (unique document identification) appears on a document in machine readable form, it can be recorded electronically, eliminating manual entry. And if it can be done simultaneously with other functions, such as recording the document on optical disk, then another labor intensive task becomes highly automated.

What are these ingenious codes that make all this possible? Numerous symbologies have come into use as the technology evolved. But today, we see that four are far more widely used than the rest. These bar code symbols are written in Uniform Product Code (UPC), Codabar, Interleaved Two of Five, and Three of Nine (Code 39) standards. While each has unique advantages for certain applications, Code 39 is most commonly used for document applications because of its alphanumeric content and nearly unlimited character length. All symbologies include start and stop characters. They can be scanned from either direction. Most have self-checking features which verify, to a high degree, the accuracy of their interpretation.

Manual data entry via the keyboard into a storage and retrieval system is hardly comparable to a bar code entry method. A trained key data entry clerk can enter data at a rate of approximately 120 characters per minute (CPM) with an approximate error rate of 1 in 300. Bar coded data can be entered at a rate of about 350 to 700 CPM with an error rate of 1 in 3 million. [Ref. 16]

While other technologies, like OCR, might guess at an imperfect character, bar code scanning will reflect it as a "No Read". "First Try" read will depend heavily on the quality of the printed code, with contrast ratio, narrow and wide element width, code density, and height to width ratio, all coming into play.

Devices used for reading bar codes can be defined as either fixed-beam or moving-beam scanners. In fixed-beam devices, like wands and photo-diode scanners, a focused light beam is passed over the bar code, or vice versa, and the modulation of reflected light from the dark bars and light spaces generates a pulse or signal. Close contact with the bar code surface is usually required. In moving-beam devices, a laser beam sweeps a pre-determined area many times per second. Neither the bar code nor the scanner needs to move while the code is being read. Both scanners usually produce an analog signal which must be converted to digital form before being transmitted to a computer or information storage device.

Document storage and retrieval systems using bar code technology need not be expensive or complex. Depending on volume and retrieval requirements, they can be PC-based and function totally independent of mainframe computers. With the use of special adapters hooked up to both the host computer and bar code scanner, bar coded information can be used in place of manual keyboard entry to update inventory quantities, locations, prices, etc. (Figure 3-11).

In the filing of receipt and issue documents using two indexing fields (Requisition number and NSN), bar code and OCR devices can potentially eliminate the need to manually

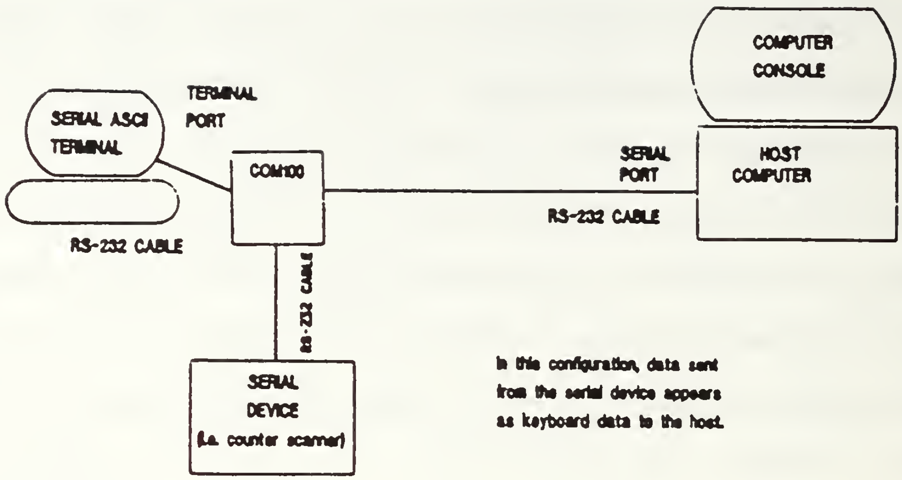


Figure 3-11. Computer to Bar Code Interface
Source: AEDEX Corporation, 1988.

enter the unique index data for each document via the computer keyboard.

4. Software

With the increasing use of automated storage and retrieval systems, comes the associated software capable of supporting stand-alone as well as several workstations working on a computerized network. Application software varies in degree of complexity and sophistication. The end-user can modify some of the software parameters and tailor the application to a particular environment.

Application software performs all functions required by the imaging system - capture, index, store, retrieve, and distribute documents. It also provides the interface function to control the operation of peripheral devices such as optical or bar code scanners, storage libraries (optical disks), workstations, facsimile machines, and printers.

5. Computer

The computer serves as processor for general and/or dedicated tasks such as application program execution, input/output control, network control and so on. Depending on the storage and retrieval functions and volume, software used, and the degree of system integration, the supporting computer can be an inexpensive microcomputer with a 80286/80386 microprocessor, or the more expensive and sophisticated line of minicomputers. In a network configuration, several workstation terminals can also be hooked up to a mainframe computer.

Monochrome or color monitors can be used to view documents. High resolution monitors are available for applications that require the viewing of complex documents such as legal and medical documents, engineering drawings, and diagrams.

6. Computer Microprocessor

The characteristics and capabilities of a computer's central processor can have a significant impact on the performance of a PC-based electronic document storage and retrieval system. The maintenance, storage, retrieval, and other database record manipulations are processor-intensive activities which requires the use of 80286 or 80386 microprocessors.

Although many technical aspects of computer design and operation are of little interest to database managers and other application-oriented information specialists, there are two microprocessor characteristics - word size and clock speed - that can have a significant impact on a system's performance in mass document storage and retrieval. As used in this context, word size denotes the number of bits that a given microprocessor can manipulate at one time. Bits are the binary elements used to encode information for computer processing. The information in this case pertains to the instructions that the microprocessor will execute. All other things being equal, the larger a microprocessor's word size, the more powerful the resulting device. Successive generations of personal computers are primarily distinguished by their use of microprocessors with progressively larger word sizes. PCs introduced in the 1970s, for example, employed 8-bit microprocessors. Reflecting the technology of the 1980s, the microprocessors now used in IBM compatible PCs feature 16-bit and 32-bit word sizes.

Word size has a significant impact on the amount of memory that a given microprocessor can address, the complexity of its instruction set, and its program execution speed. But there may also be considerable variations in speed among microprocessors with identical word sizes. All microprocessors are equipped with timing circuits operating at a predetermined clock speed, which is measured in millions of cycles per second or millihertz (MHz). The clock speed denotes the rate at which a given microprocessor performs operations. Microprocessors with larger word size typically have faster clock speed. The speed of a given microprocessor may vary from one PC configuration to another.

7. Image Storage Device

Once an image has been captured and indexed, it can be stored in the imaging system. The rapidly expanding market for mass storage devices provides any user with a flexible range of storage options from high-volume optical disks to magnetic disks. The storage devices can be used exclusively or in various combinations, depending on your budget, storage space, and application needs.

Image storage can be optical disk-based, microfilm-based, or magnetic disk-based, or a combination of optical drives, microfilm units, and magnetic disks. With a disk-based system, document images are scanned or digitized to optical disks, or to magnetic disks using a document scanner, and are indexed using a user-specific program.

8. Printer

There are various types of printers capable of supporting a basic imaging system. The two most commonly used are "dot-matrix" and "laser" printers. They vary in speed, printer resolution, paper-handling capabilities, font style and size,and of course - cost. Any image, regardless of how it is stored, can be printed out in hardcopy form on any image-capable printer.

Most electronic document imaging systems support a laser printer to provide hardcopy output from database records and reproduce digitized document images. Operating at speeds ranging from 6 to 20 pages per minute in personal computer-based equipment configurations, laser printers typically offer a choice of resolutions ranging from 200 to 400 pixels per horizontal and vertical inch, although hardcopy output quality is ultimately limited by the resolution at which document images are scanned and stored.

9. Facsimile Machine

Facsimile (FAX) machines are now widely used worldwide. They are used with standard telephone lines to send and receive hardcopy printouts of text and image documents. A FAX image can be sent from any CCITT Group 3 or Group 4 FAX machine to the recipient's FAX machine or directly to an imaging system workstation. In a similar fashion, the user of an imaging system can locate an image, choose a FAX destination using a telephone MODEM attached to the computer, and transmit the image accordingly.

We have discussed an overview of current technologies in document storage and retrieval systems. The characteristics and limitations of document imaging systems were presented. The hardware, software, and other peripheral devices associated with these imaging systems were described.

IV. OPTICAL MASS STORAGE TECHNOLOGIES

A. HISTORICAL OVERVIEW OF OPTICAL TECHNOLOGY

There is some argument about the exact names and dates associated with the birth of optical technology. Some authorities claim optical technology began in 1877 with Thomas Edison's invention of a voice recorder that recorded and played back voice recordings on a wax cylinder. Others claim that it began with Reginald Friebus who invented the optical videodisc in 1929. Friebus' invention reproduced sound from beams of light reflected from a disk pressed from a wax master.

Most research in those early years involved the feasibility of various methods for disk creation and playback. This led to the separate developments of the recording and replication of video information on videodisc and much later to the real-time recording of digital data on a computer storage device.

In this decade, we have seen the massive use of personal computers in virtually all business and professional applications. The Department of Defense continues to be the single biggest recipient of information technology, most of it in the form of installed software and microcomputers. Cheaper, faster, and more capable personal computers displaced large numbers of traditional minicomputers and established new uses and applications for computer technology.

Today, it is almost impossible to think back and realize that the initial microcomputers marketed by Apple Computers and IBM had no hard disk storage at all; floppy disk was the only rotating mass storage device available. When IBM announced the PC/XT microcomputer in the early part of this decade, a 10 MB drive was offered as an optional mass storage device. PC-DOS (Disk Operating System) was used as the computer operating system. It was designed to support a maximum hard drive capacity of 32 MB, a capacity that was thought at the time to be adequate for any personal computer application.

Enormous advances in both microcomputer and disk drive technology have taken place since the initial introduction of personal computers. Disk drive capacities of 20 to 160 MB are now routinely installed on today's personal computers. More demanding and complex applications require capacities of 300 to 650 MB in single user systems. Local Area Networks (LANs) configured to support computer workstations frequently exceed one gigabyte (GB) storage capacity on the file server.

The rapid growth in disk drive capacities supported a truly demanding size of on-line databases. Along with the massive growth of information that can be stored in microcomputers, the computer industry began looking for methods to cope with the constantly increasing problems associated with this database explosion. Alternative technologies were quickly introduced to satisfy requirements such as hard drive backup, off-line storage, archiving of data, physical transportation of large amounts of data, and secure storage of sensitive data. These technologies have been varied and unique. They include high density floppy disks, cartridge tape, reel-to-reel tape, Computer Output Microfilm (COM), removable media hard disk drives, and removable Head Disk Assembly (HDA) drives. Each one of these technologies has their own advantages and limitations. In each case, a significant advantage of the technology or product is generally matched by an equally unattractive weakness.

"Optical Disk Drives" use a laser beam instead of a magnetic field to read and write data. With over ten years of research and development, optical technology now offers random access on removable media with extraordinary data density at very competitive prices. Using optical drives of various sizes (3.5" to 14"), gigabytes of data can be on-line to a personal computer for access within seconds. Data can be stored off-line for about 50 cents per megabyte. Businesses and government agencies are turning away from the older storage devices such as tape drives and removable media magnetic disk drives in favor of optical storage for archiving data and storing large databases. Although file access and transfer speed remain an advantage for magnetic disk drives, storage capacity and handling considerations are strong selling points for optical disk drives. Figure 4-1 presents a comparison between optical and magnetic media storage devices. [Ref. 17],[Ref. 18]

B. MECHANICS OF OPTICAL TECHNOLOGY MEDIA

There is no one component of optical storage technology that can stand alone and be identified as the specific technology. Optical storage encompasses, and is dependent on, a variety of technological developments - voice, and later video recording, digital recording of data in a computer environment, laser technology, automated manufacturing, and software programs for word processing and data retrieval. Although an optical imaging system consists of other various individual technologies such as optical and bar code scanners, application software, monitors, and printers, mass data storage is considered its most critical element.

Although all media formats of optical storage technology require a laser beam to record and then later to read stored information, the similarity among the different formats ends there. A videodisc, a compact audio disk, Compact Disk - Read-Only Memory (CD-ROM), or any read-only media, is mastered and then replicated in quantities in a manufacturing facility. Typically, such disks followed prescribed standards.

MEDIA	Small Winchest.Disk	Large Optical ROM	5.25" Floppy Disk	1/2" Magnetic	Large Winchest.Disk	CD-ROM	5.25" WORM Disk
Media Cost ($)	N/A	15-30	1-5	10-20	N/A	10-20	95-150
Drive Cost ($)	500-3,000	7,000-100,000	200-1,500	3,000-15,000	10,000-250,000	500-2,500	5,000-15,000
Capacity (in MB)	5-50	1,000-4,000	0.36-1.20	30-300	50-4,000	540-680	200-300
Cost per MB ($)	63.63	21.41	1093.59	54.64	39.51	2.48	17.40
Media Size (in.)	5.25	12.00	5.25	10.50 REEL	14.00	4.72	5.25
Access Time (sec)	.03-.30	.03-.40	.003-.05	1-40	.01-.08	.5-1.5	.01-.5
Density (bits/in.)	15,000	35,000	10,000	6,250	15,000	35,000	23,000
Data Rate (KB/sec)	5,000-10,000	8,000-40,000	30-1,000	100-10,000	8,000-40,000	500-1,200	500-4,000

Figure 4-1. Optical vs Magnetic Storage Device Comparison
Source: CD-ROM Optical Publishing, p.37.

Write-Once-Read-Many (WORM) and erasable optical media, on the other hand, are initially blank. The optical disk drive uses one or two lasers having variable intensities, one to "burn" the data onto the disk and another to read the data without altering the existing data.

You can divide optical storage devices into three categories, according to the permanence of the data they store: ROM (read-only memory); WORM (write once, read many times); and read-write-erase media. The categories of media differ in the precise way they write and read the stream of digital "dots" that have been written onto the media. Since there are both significant and subtle differences among all methods of storing and retrieving information from these various optical formats, a detailed description of each storage device follows.

1. Compact Disk Read Only Memory (CD-ROM)

By far the most popular and well known form of optical storage technology is the CD-ROM. It is also the most technologically developed of the three types of optical disk. Its popularity is largely due to the overwhelming acceptance in the record music industry of the compact disk (CD) as the state-of-the-art device in reproducing the fidelity of live music. The CD-ROM media uses a 120 millimeter (mm) plastic disk, similar to an audio CD, with digital information mechanically stamped into the media surface as tiny indentations from a master disk. Although generating the master disk is expensive, copies can be mass-produced inexpensively. The disk is stamped in high volume with a single spiral groove that covers the surface of the disk. Encoded in the groove is a series of indentations that represent digital "ones" and "zeros". The information is always placed on the media in this manner and it cannot be overwritten or modified by the user. When updated information is needed, CD-ROM disks can be sent out periodically.

The indentations in the grooves are read by aiming a precisely focused laser beam at the groove and monitoring the presence or absence of reflections which coincide with the presence or absence of indentations in the groove. Figure 4-2 illustrates this process. The electronics on the CD-ROM device then reconstruct this information into a stream of data that can be sent to a personal computer or a stereo amplifier. In the case of the stereo amplifier, the data are first passed to a Digital to Analog Converter (DAC) device which transforms the digital data values into an analog waveform that can be amplified and sent to the speakers as audio voltage signals. When the connected device is a personal computer, the data are sent directly to the computer via a control board. A program in the personal computer then properly interprets this data and sends them to the application program as appropriate.

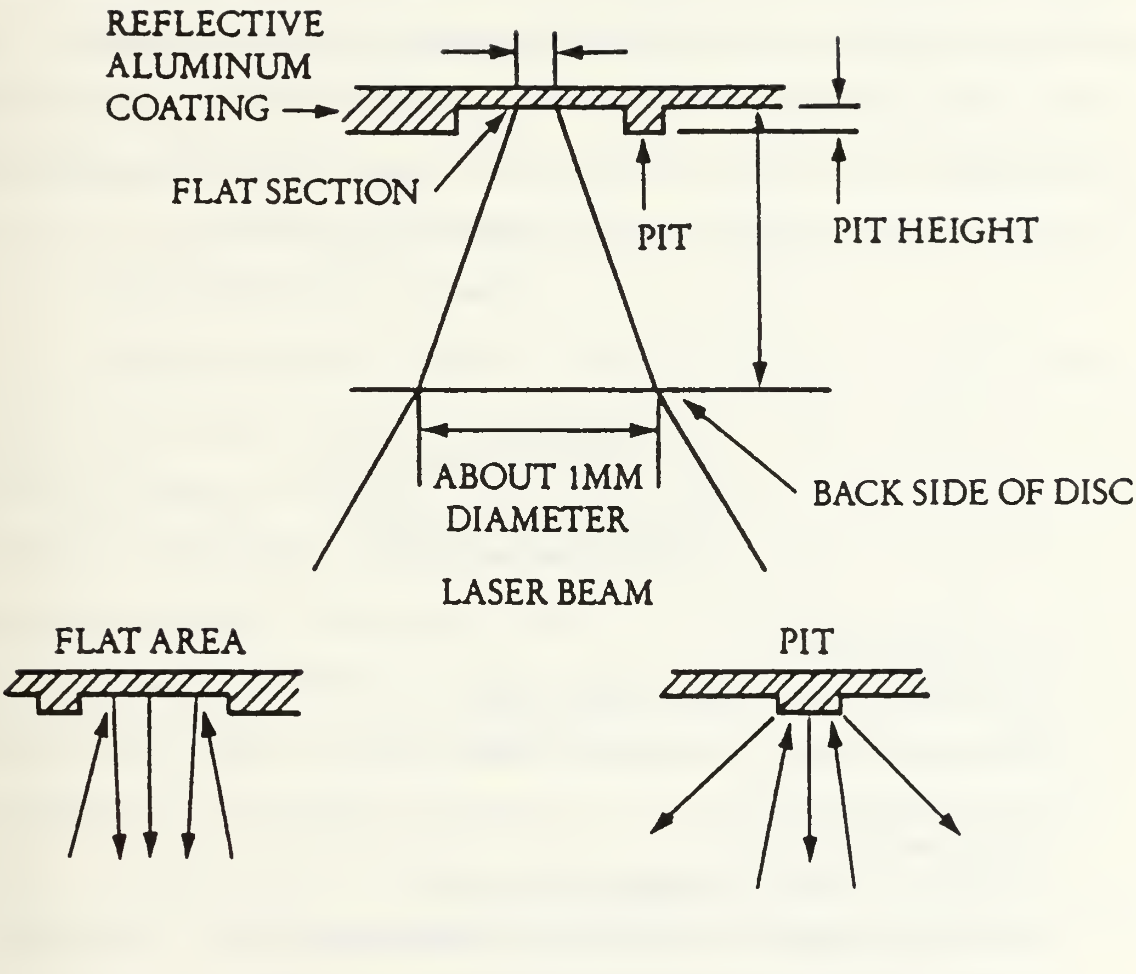


Figure 4-2. How CD-Rom Works

Source: CD-ROM The New Papyrus, Microsoft Press, page 60.

CD-ROM is rapidly gaining popularity as a distribution medium for reference data that change infrequently. A growing number of catalogs, specialized databases, digitized data, and software programs are being delivered on CD-ROM as personal computer users realize the advantages of having 600 MB of data that can be accessed randomly and loaded into the computer within seconds. The 600 MB capacity translates to approximately 270,000 pages of printed text - more pages than contained in the largest encyclopedia in print today. In fact, Grolier Encyclopedia is already available in CD-ROM form [Ref. 19]. Table 4-1 further illustrates the equivalent storage capacity of a 5.25" CD-ROM disk [Ref. 20].

TABLE 4-1
CD-ROM CHARACTERISTICS

A SINGLE CD-ROM CAN HOLD THE SAME
INFORMATION HELD BY:

270,000 PAGES OF TEXT OR,

20,000 PAGES OF IMAGES SCANNED AT 300 X 300 DPI OR,

10,000 PAGES COMPRISED OF 1/2 TEXT AND 1/2 GRAPHICS OR,

1,500 5 1/4" FLOPPY DISKS OR,

1,200 MICROFICHE CARDS OR,

1,104 HOURS (46 DAYS)OF DATA TRANSMISSION AT 1200 BAUD

27-20 MB WINCHESTER DISKS OR,10 STANDARD 1/2", 9-TRACK TAPES, OR,

1 HOUR OF FULL MOTION, FULL SCREEN, FULL COLOR VIDEO.

Source: Lind Thesis CD-ROM 5.25 Disk Comparison, p.24

CD-ROM is the only one of the three optical storage methods that adheres to a standard format. Almost all commercial CD-ROM products and players follow the International Standards Organization (ISO) 9660 standard. ISO 9660 established standards on how data is to be represented on CD-ROM optical disks. These data include volume, directory, and file structure between all common operating systems. [Ref. 21]

Table 4-2 lists the advantages while Table 4-3 lists the disadvantages associated with CD-ROM media. Table 4-4 provides a concise list of technical characteristics and formatting methods pertinent with a CD-ROM disk [Ref. 22].

2. Read-Write-Erase Media

Until recently, optical disks available in the market could record data only once on the disk. Once recorded, the data can never be erased. In 1987, teams of engineers at 3M Company and other leading disk makers, such as Sony and Maximum Storage, discovered almost simultaneously how to make an ultra-thin magnetic layer that could be written on and erased many times without deteriorating. This storage device represents the latest technology in using laser beams to store data. As the name implies, the technology offers rewritable capability, making the drive appear nearly identical to drives that utilize magnetic recording techniques.

TABLE 4-2

CD-ROM STORAGE MEDIUM ADVANTAGES

PERMANENT/DURABLE: It is an excellent archival medium (currently Sony disks are guaranteed for 50 years.) Also very rugged and able to withstand adverse weather and handling conditions.

NON-VOLITATILE: No loss of altering of data during power failure or surges.

LOW COST: The 'per MB' cost of data is less than any storage medium.

EXTREMELY PORTABLE: The media is removable and offers portability of data. Disc maintenance is extremely easy (ie. soap and water wash annually).

SECURITY: Physical control can be maintained easily and thus large quantities of sensitive data can be controlled. Also, the possibility exists to manufacture the disk out of glass instead of polycarbonate material and thus, for military purposes emergency destruction could be easily accomplished.

SMALL VOLUME/WEIGHT: Easily carried, mailed etc, at a very low expense.

UNALTERABLE: Media is Read Only Memory (ROM) and as such, it is extremely useful for audit trails in a legal/financial environment; magnetic media has not been allowed as evidence due to media alterability.

ENORMOUS DATA STORAGE CAPABILITY: Up to 600 MB of data on a single side of a single disk which is only 4.72 inches in diameter.

USER FAMILIARITY: It is simply another PC peripheral that, to the user, looks just like a read only MS-Dos etc. disk. Also, the average user has had experience with the same physical disk in the CD-Audio environment and therefore feel more comfortable with it all ready.

BACKUP IS ELIMINATED: There is no need to backup the disk because it is ROM. For safety sake, multiple copies can be ordered at the time of disk pressing and stored in separate locations.

ELECTRO-MAGNETIC PULSE (EMP) HAS NO EFFECT: This is not a magnetic media and therefore any sort of electro-magnetic energy has no effect on it.

NO HEAD CRASHES: The read-device is optical and does not contact the disk in any way, therefore, head crashes are virtually eliminated.

MULTI-MEDIA POTENTIAL: The new CD-I and DVI multi-media, interactive capabilities have tremendous implications for a training/how-to application.

EXTREMELY LOW ERROR RATES: Due to the extensive ECC available from enormous storage areas, error rate = 1 error in a quadrillion bit (1 + 15 zeros).

Source: Clarey Thesis, CD-ROM Advantages, p.59.

TABLE 4-3
CD-ROM STORAGE DISADVANTAGES

READ ONLY: This feature, while a benefit to some applications, is a hindrance to others desiring to alter their data.

INITIAL COSTS FOR ADDITIONAL HARDWARE: Although this is true of any new system, it is viewed by many as a disadvantage when compared against the all ready sunk costs of the presently installed system.

SLOW ACCESS SPEEDS: The average time to retrieve data, when compared to hard disk, etc. is much longer.

DATA PREPARATION COSTS: Indexing, retrieval software,and revision replication costs for dynamic (new weapon systems) databases may not be as economical as alternative media not requiring as extensive data preparation.

Source: Clarey Thesis, CD-ROM Disadvantages, p. 59.

TABLE 4-4
CD-ROM CHARACTERISTICS

SIZE:	4.72 INCHES
STORAGE CAPACITY:	UP TO 600 MB
DATA TRANSFER RATE:	1.5 MB/SEC
ROTATION SPEED:	200 RPM (OUTER TRACKS)
	500 RPM (INNER TRACKS)
ACCESS TIME:	APPROX. 0.5 - 1 SECONDS
ROTATIONAL LATENCY:	60 - 130 MILLISECONDS
TRACK CHARACTERISTICS:	CONSTANT LINEAR VELOCITY (CLV)
TRACK LENGTH:	3 MILES (READING STARTS AT THE INNER TRACK)
AVERAGE PIT SIZE:	1 MICRON
AVERAGE TRACK SEPARATION:	1.6 MICRONS
INFORMATION RECORDING:	ONE-SIDED ONLY

Source: Clarey Thesis, CD-ROM Disk Characteristics, p. 59.

There are three types of erasable optical media, each with variations in their appropriate rewritable mechanism.

a. Magneto-optic

This disk drive combines a laser and a magnetic coil which work in tandem. Each minuscule data storage spot on a blank disk is magnetized in the same direction. As illustrated in Figure 4-3(a), the blank disk's north pole points in the downward direction. This magnetic orientation cannot be changed unless the disk is heated. To inscribe digitized data, an infrared laser rapidly heats selected data-storage spots on the disk. A magnetic coil flips the north pole up to signify a binary "1" or leaves it pointing down for a binary "0". Figure 4-3(b) illustrates this process. To read stored data, a laser beam of weaker intensity bounces off the disk. The light is polarized clockwise or counterclockwise, depending on which way a data spot is magnetized. The disk drive then deciphers the signals to read the data. Figure 4-3(c) shows this process. To erase the data stored in the disk, the magnetic coil reverses its field. The laser heats all the data spots, causing the polarity to orient downward again as shown in Figure 4-3(d).

b. Phase Change

This technology uses high power laser to heat the surface of the medium to a high temperature for a very short period of time, usually less than 100 nanosecond (ns).

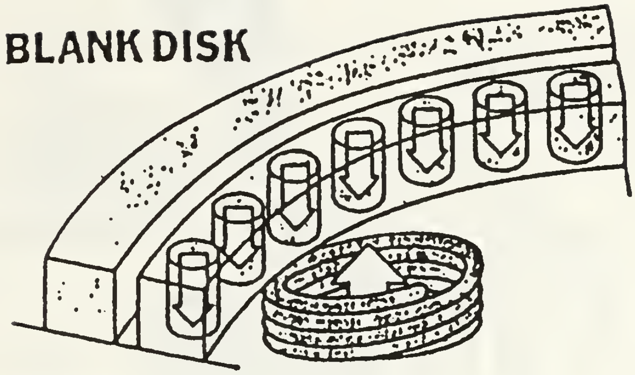


Figure 4-3(a). How an Erasable Disk Works
Source: FORTUNE, January 1989.

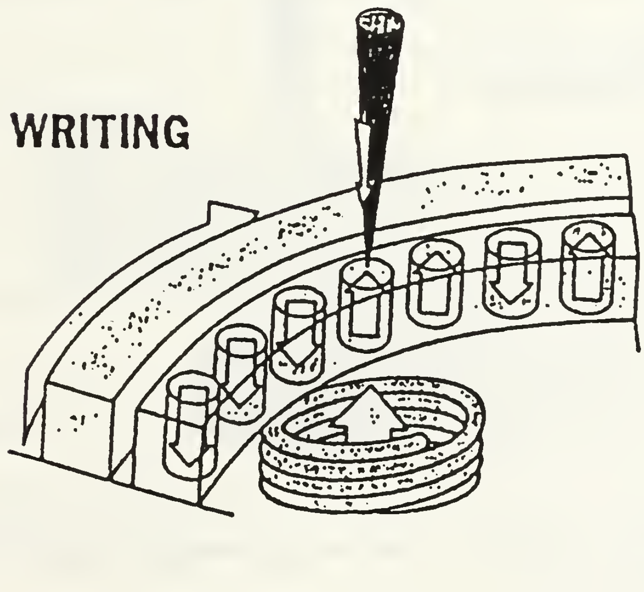


Figure 4-3(b). How an Erasable Disk Works
Source: Fortune, January, 1989.

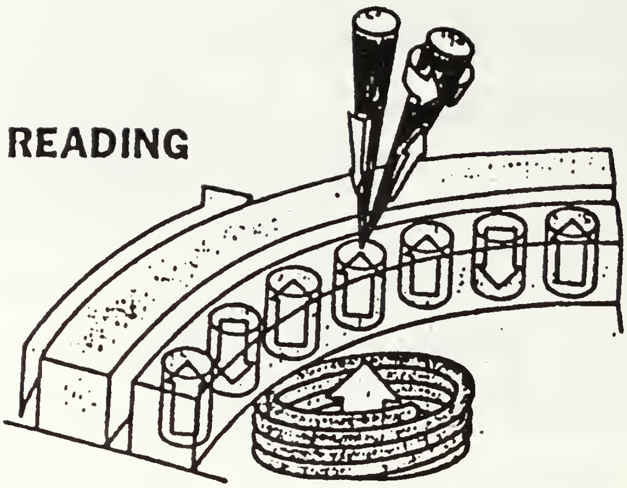


Figure 4-3(c). How an Erasable Disk Works

Source: FORTUNE, January, 1989.

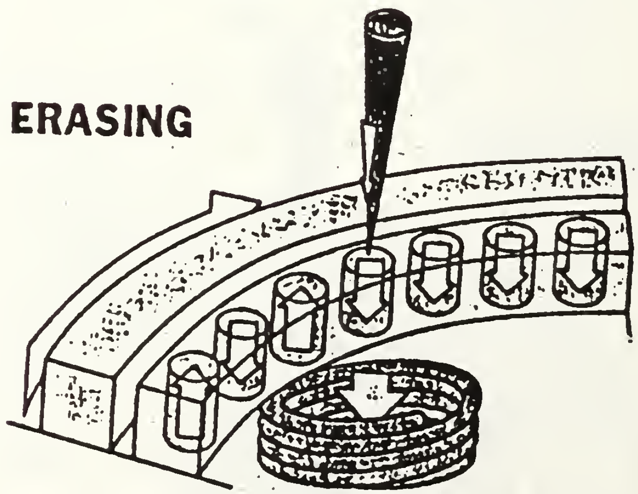


Figure 4-3(d). How an Erasable Disk Works

Source: FORTUNE, January, 1989.

Instantly after the heating process, the medium cools rapidly to an amorphous state. The amorphous areas have lowerreflectivity than crystalline areas. They are read in similar way as Read-Only technology. To erase the inscribed data, the surface of the medium is reheated for a much longer period of time, usually 1 to 5 millisecond (ms) and then allowed to cool off slowly.

c. Polymer Dye

This technology uses a similar write and erase process as employed in the phase change technique. To inscribe data, a high powered laser beam is directed to heat a heat sensitive track of an alloy made of silver and zinc. This metal combination changes color when heated at various temperatures. Unlike the Phase Change technique which uses the differences in light reflectivity to read and write data, this process uses differences in color to transform data into binary representation.

Over the years, debates have occurred surrounding the appropriate rewritable technology and disk size to use. The Magneto-optic erasable disks appear to be the leading contender with several products already out in the market. Maxtor Company of San Jose sells the Tahiti I, a 5.25" erasable optical disk drive with 1GB of formatted storage capacity at $5,995 [Ref. 23].

The advantages of erasable optical technology are clear. The media: 1) is rewritable, 2) is removable, and 3) has high capacity storage. The disadvantages are also equally clear: 1) there is no industry standard to support the technology, 2) the drives and media devices are much more expensive than other existing optical media, 3) the technology has not yet been field proven for reliability in live applications, and 4) erasable storage devices are not yet available in high volume production quantities.

3. Write-Once Read-Many (WORM)

Since the focus of our research involves optical disk technology for **"real-time"** shipboard applications, specifically for storage and retrieval of receipt and issue documents, we will analyze and explain in detail the current technological capabilities of WORM storage media.

Unlike CD-ROM and other Read-Only media, the WORM optical media can be recorded at the local worksite. The limitation is that data can be written to a sector only once. Like Read-Only media, the Write-Once drives allow the user to read the stored data from an optical disk for an infinite number of times. Writable systems use a single laser with two heat intensities or, less often, two different lasers to write and read in a single drive. The Write-Once optical disk becomes both the mastering system and the delivery system.

Figure 4-4 shows a block diagram of the logic, optics, and laser configuration of a typical optical drive [Ref. 24].

a. Write-Once Media Types

A basic understanding of the variations among optical Write-once media and Write-Once systems will help explain the different recording techniques. According to 3M, there are about 194,400 options in media types possible [Ref. 25]. This conclusion is based on a list of Write-Once optical media options available today (see Figure 4-5). Not all the variables listed will be explained since some are too technical and some are self-evident. However, there are some variables that may make a difference. The durability and longevity of the media may be critical requirements for one system; for another, cost may be the deciding factor.

The two primary substrates used for Write-Once media are plastic or optical-grade polycarbonate and glass. With a plastic substrate, the media is more easily mass produced and therefore less expensive than glass. But it is also more susceptible to imperfections during construction. Optical media with glass substrates are less susceptible to imperfections and dimensionally more stable than plastic substrates, but less amenable to mass production since it must be flawless, and therefore more expensive to produce. Also, glass is breakable.

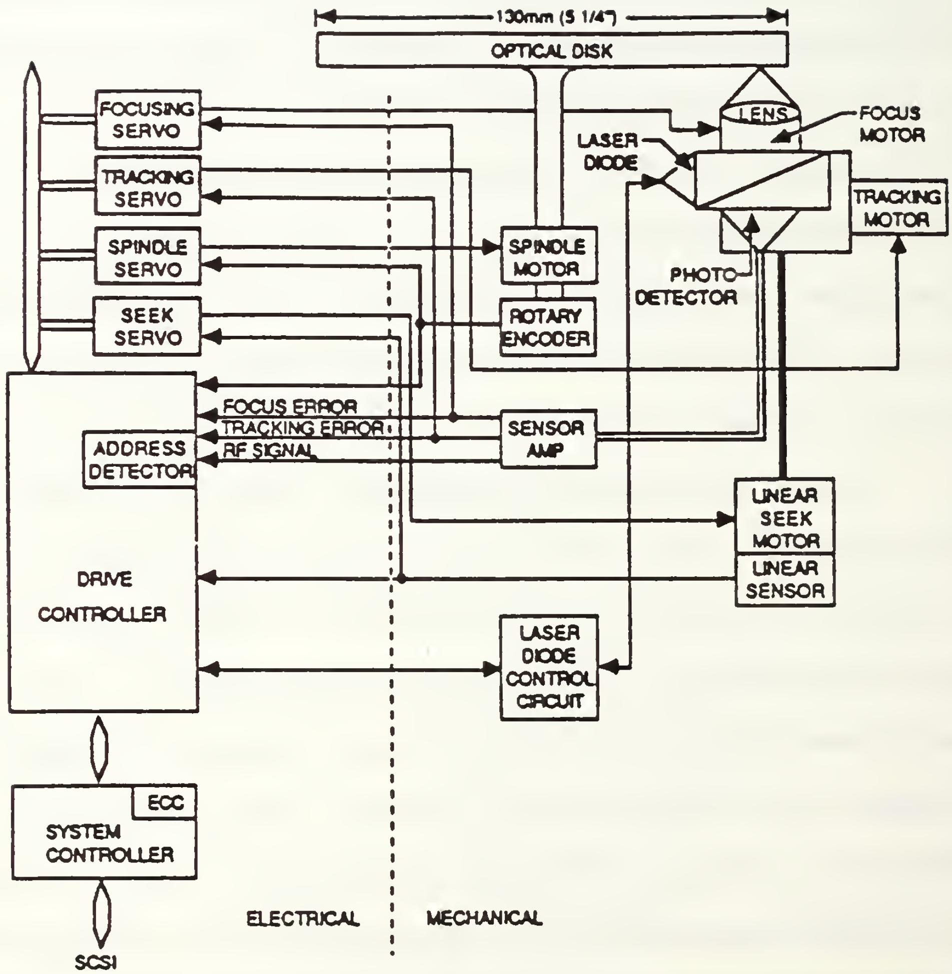


Figure 4-4. Block Diagram of Typical Write-Once Drive

Source: Storage Dimensions - MAXTOR Company, 1989.

ELEMENT	OPTION
Substrate	– Glass – Aluminum – Plastic
Construction	– Air Sandwich – Sealed Laminate – Core Sandwich – Flat Sheet
Mechanism	– Bubble Former – Bit Former – Alloy Former – Phase Change – Dye Ablate – Dye Bleach
Detection	– Absorption Change – Reflectance Change – Optical Phase Change
Protection	– None – In Contact – Off Contact
Active Layer	– Monolayer – Bilayer – Trilayer – Quadrilayer
Tracking	– Nongrooved – Grooved Track – Intermittent Track – Push-Pull – Wobble
Format	– Preformat – Non Format (User) – Post Format
Encoding	– One for each drive system
Sizes	– 14" – 12" – 8" – 5.25" – 4.72"

Figure 4-5. Write Once Optical Media Options Available Today

Source: Association for Information and Image Management, Silver Spring, Maryland, 1988.

The different Write-Once media types can be classified into three categories: pit forming, bubble forming, and color change. In each technique, the high-power, solid state laser heats the active layer of the media and causes a change in the form of a pit, bubble, or color. At present, there are three types of media in popular use:

(1) Tellurium Oxide and Alloy. This is by far the most widely used medium and the earliest to be developed. The disk platter is coated with this alloy because it heats rapidly, enabling relatively low powered lasers to create a pit in the media. Data are represented by pits melted into the recording surface by the laser. This technique, often referred to as "ablative pit", offers long media life, but requires expensive techniques to deposit the metallic layer on the substrate.

(2) Bimetallic Alloy. This technique was developed by Sony which is a variation of the first technique described above. It involves depositing two successive metallic layers on the disk surface. During the writing process, the laser heat causes the upper and lower layers to fuse, creating an alloy that has a different reflectivity than that of the upper layer. This media is claimed to have a longer life than the ablative pit technique discussed earlier. This media is also the most expensive due to the additional metallic layer added to the substrate.

(3) Dye-based and Dye-polymer. Dye polymer is the newest substrate coating available on the market today and perhaps the least expensive. The substrate is coated with a recording layer that consists of a dye-polymer material which can be altered locally by heating a spot to record data. The dye-polymer media can be easily manufactured using a simple spin-coating equipment. The same spin-coating technique is widely used in the manufacture of floppy disks and oxide-based Winchester disks. The dye-polymer media can be manufactured with lower production costs compared to the other media produced by sputtering. As production volume increases, the dye-polymer media is expected to cost substantially less than other metallic media types.

b. Write-Once Recording

The objective in the recording cycle of Write-Once optical disks is to alter the reflectivity of a series of minuscule spots or pits on the blank optical disk. During the read cycle, a laser beam either reflects back to the photo sensor or is diffused, indicating the presence or absence of data (i.e., digital ones and zeros). There is no single standardized method for altering the optical disk during the write cycle. Indeed, there are many different recording techniques. Most issues concerning the lack of standardization of optical media stem from a myriad of methods and techniques for "writing" data onto a recordable optical disk.

Figure 4-6 illustrates the steps involved when writing to an optical disk for the ablative process using a disk that is pre-grooved for servo tracking and pre-formatted with sector address information. There are various ways to achieve bit formation on the optical disk. The bit can be a shiny spot on an otherwise non-reflective disk surface or a non-reflective spot on a shiny surface. The bit can be inscribed on the disk as a bubble or as a pit. It can also be a spot of a different color from the rest of the disk surface or a spot with different reflectivity from the surrounding disk surface. On such disks, the laser changes the crystalline structure of the disk's surface in order to change the reflectivity of the spot.

In a WORM drive that uses an ablative-pit recording method, the media is pre-grooved and formatted with clock information. The data is then burned in as shown in Figure 4-6(a), and later appearing as a hole after the heating process as shown in Figure 4-6(b). As shown in Figure 4-6(c), clock information appears as a series of bubbles (left) and the data as fringed holes (right). The data is arranged in sectors as illustrated in Figure 4-6(d), much like magneticdisks, except that each sector begins with a write-protect field to prevent overwriting and destroying existing

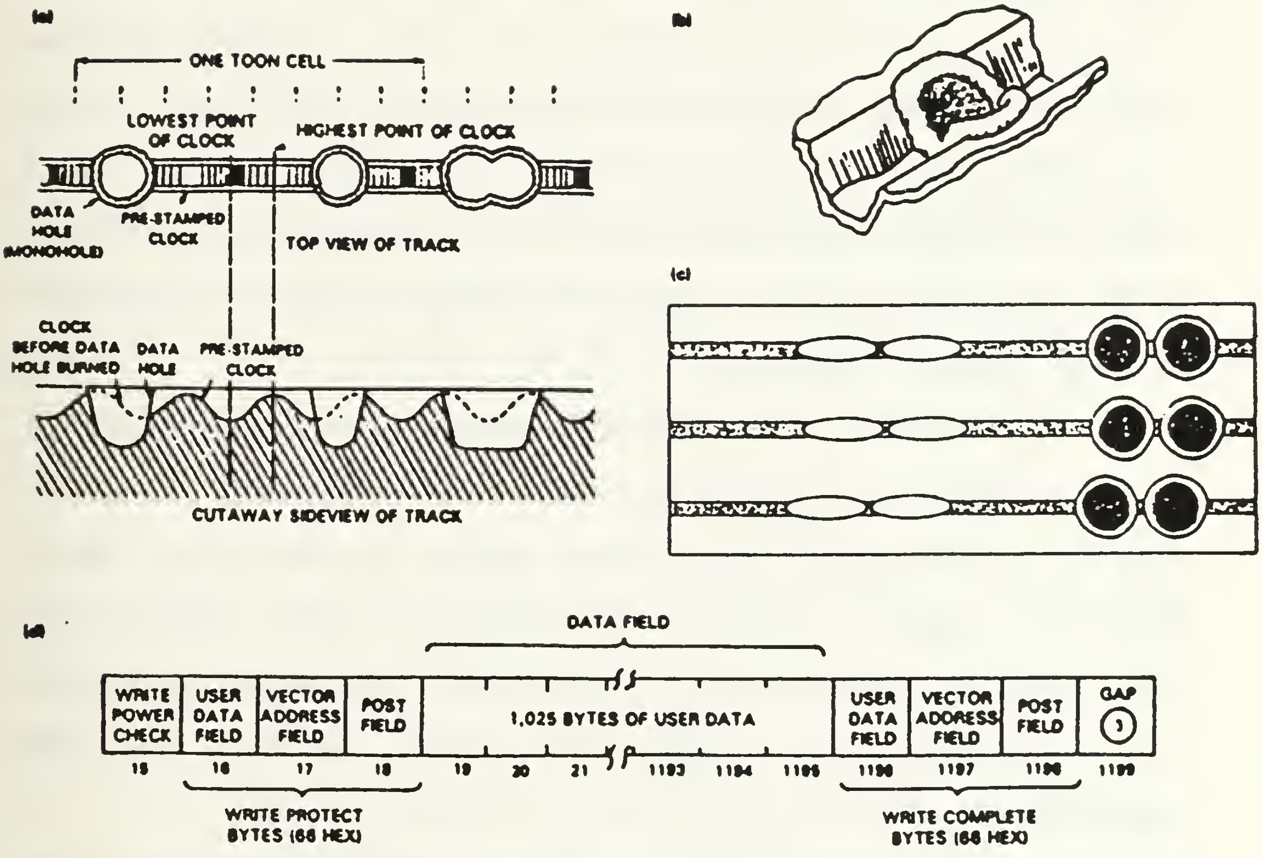


Figure 4-6. Creating WORM Media

Source: Association for Information and Image Management, Silver Spring, Maryland, 1988.

data. The write protect fields are followed by the user-data field and the write-complete field. The latter points to either a new sector if an error was encountered during writing, or to a new data record if the record was updated.

c. Write-Once Reading

To read data from the optical disk, light from the laser beam is either deflected, indicating the absence of data, or reflected, absorbed, or detected in some other manner that will indicate the presence of data. For the reading cycle to occur properly, three situations must occur simultaneously: (1) the laser must be focused, (2) the laser must be aligned with the track, and (3) the data signal must be received accurately. There are several ways to accomplish each of these situations.

Methods of detecting whether or not the laser is focused accurately rely on the detection of spatial patterns. Errors in detecting the correct spatial pattern can result from the light reaching the wrong quadrant caused by misalignment, media defects, or failure of an exact point-to-point correspondence between the reflective layer and the detector.

Detecting tracking errors can also rely on the sensing of spatial patterns as in the case of pre-grooved media. With pre-pitted media, tracking errors are detected by an embedded servo-mechanism which continuously senses the intensity of the beam and adjusts it accordingly. Errors in either focusing or tracking will cause a loss of signal synchronization.

In addition, optical drives also have a means to detect and then correct errors in the data itself caused by the tracking or focusing errors, hot spots in the laser, shock and vibration, heat, and other environmental effects. The error correction codes are typically embedded within the recorded data.

Write-Once drives use two basic methods of spinning the disk to store data. Some spin the disk media with constant angular velocity (CAV), or the same rotational speed (RPM) at all times. Others spin the disk with constant linear velocity (CLV), a method which ensures that the velocity of the spinning disk directly under the optical read/write head is always the same. In order to perform the latter, the RPM of the disk must be varied as the head moves from the inner to the outer radius of the spinning disk. Rotation is fastest when the head is near the center of the disk and slowest when the head is at the disk's outer edge.

The CLV method was developed in order to maximize the amount of data that can be stored on a single removable cartridge. This method permits the density of written data to be at its maximum throughout the disk platter. This means that the storage density is the same on the innermost and outermost tracks of the media.

The CAV method, on the other hand, shares the same limitations of Winchester magnetic media. The maximum density always occurs at the innermost track of the disk. Each concentric track is slightly longer in circumference than its immediate inside neighbor, yet the number of bits stored per track is the same for all tracks. As such, maximum capability of the media is exploited only in the innermost tracks while the density decreases toward the disk's outer rim.

The CLV drive, which is more complex in operation than CAV drives, can store significantly more data, but has a somewhat slower access time because of the need to change media rotation speed when the head is moved. Most WORM drives in the market spin their disk's with CLV speed control.

Table 4-5 provides a summary of the advantages and disadvantages associated with WORM storage media. Table 4-6 illustrates the equivalent storage capacity of a 5.25" WORM disk. Table 4-7 provides a concise list of technical characteristics pertinent to a WORM disk.

Although there is currently no industry standard pertinent to the physical or data layout of WORM media, we considered this issue as irrelevant due to the unique filing and storage requirements of each Navy ship. Each ship has a unique series of Requisition numbers for every fiscal year.

TABLE 4-5

WORM STORAGE MEDIA ADVANTAGES AND DISADVANTAGES

ADVANTAGES

MASSIVE DATA STORAGE CAPABILITY: Similar storage potential of CD-ROM; approx. 1/3 capacity of similar sized disk.

REAL TIME DATA STORAGE: Data stored at 'terminal', no data preparation or replication costs, immediate availability/ access to stored data.

LOCAL STORAGE APPLICATIONS:In-house data control, alleviates security issues of data preparation and mastering at external replication site.

ARCHIVAL BACK-UP: Stabilized/indexed magnetic data to WORM back-up.

AUDIT TRAIL BENEFIT: Investigate transactions and historical actions.

ENVIRONMENT TOLERANCES: Better environmental tolerance/durability than magnetic media- less than CD-ROM (EMP, head crashes, dust)

SMALLER USER BASE REQUIRED: Cost benefit trade-off requires smaller scale data base distribution effort vs. CD-ROM disc replication costs, two to twenty 'users' in a local network area (LAN) could justify WORM usage

LOW COST: Low cost/ bit, more expensive that CD-ROM due to writing tolerances and WORM disk composition, but much less that magnetic formats.

FASTER RANDOM ACCESS (CAV): Constant RPM and hard-sectored disks enable faster data access, faster with pre-indexed data prep.

PERMANENCE: Write-once technology offers virtually permanent data storage which cannot be accidentally erased or damaged through static electricity, magnetic fields, or other environmental factors lethal to standard magnetic disks or tape storage.

REMOVABILITY: Write-once technology is the most secure and compact removable storage available. The permanent nature of write-once storage makes it impervious to many of the natural elements which have affected removable disk and tape storage in the past.

TRANSPORTABILITY: Due to the small size, high storage density, and ruggedness of a 5.25" cartridge, it can be used to distribute large amounts of data conveniently and economically between sites.

DISADVANTAGES

LASER HEAD COMPLEXITIES: Two laser heads required for read/write operations-ruggedarzation problems with exacting tolerances of WORM.

DISK REVISION OR ERROR CORRECTION ISSUES: Inability to write over a mistake or to make minor revision/updates in the 'burned' read-only data.

LACK OF PHYSICAL OR LOGICAL STANDARDS: WORM industry proprietary concerns have precluded a disk medium physical or data layout standard.

COMPLEX INDEXING/SEQUENTIAL WRITES: Real-time data goes to disk sequentially, efficient indexing for logical data access must be done prior or after 'burning' process on a second WORM disk.

AVERAGE ACCESS TIME: With poor indexing or data layout (resulting from sequential writes), access time suffers compared to erasable media that can shift data blocks to accommodate logical addressing.

DISK COSTS AND ALLOY SUBSTRATE STABILITY: Long term life-cycle and WORM medium applications in extreme military environment not fully tested.

Source: Clarey Thesis, WORM Advantages/Disadvantages, p.61.

TABLE 4-6
WORM DISK EQUIVALENT CAPACITY

<u>A SINGLE WORM (5.25") CAN HOLD THE SAME INFORMATION HELD BY :</u>

100,000 PAGES OF TEXT OR,

8,000 PAGES OF IMAGES SCANNED AT 300 X 300 DPI OR,

3,500 PAGES COMPRISED OF 1/2 TEXT AND 1/2 GRAPHICS OR,

600 5 1/4" FLOPPY DISKS OR,

450 MICROFICHE CARDS OR,

408 HOURS (17 DAYS) OF DATA TRANSMISSION AT 1200 BAUD OR,

10 20-MB WINCHESTER DISKS OR,

4 STANDARD 1/2", 9-TRACK TAPES

Source: Clarey Thesis, 5.25" 300 MB WORM Disk Capacity, p. 57.

TABLE 4-7
WORM TECHNICAL CHARACTERISTICS

<u>WORM CHARACTERISTICS:</u>

SIZES: 3.25", 5.25", 8", 12", 14"

STORAGE CAPACITY: 300 MB- 5.25"; 3.6GB-12"

<u>5.25" WORM DISK (CAV):</u>

DATA TRANSFER RATE: 5 MB/SEC

ROTATION SPEED: 1800 RPM (CAV)

ACCESS TIME: AVE. SEEK APPROX. 0.02 SECONDS

ROTATIONAL LATENCY: 16.7 MILLISECONDS

TRACK CHARACTERISTICS: TRACKS: 14,500; SECTORS:32/TRACK
512 BYTES/SECTOR

AVERAGE PIT SIZE: 1 MICRON

AVERAGE TRACK SEPARATION: 1.6 MICRONS

INFORMATION RECORDING: TWO SIDED

Source: Clarey Thesis, Worm Disk Characteristics, p. 56.

A ship's receipt and issue file is of little use to other activities. Presently, there is also no requirement for a ship to widely disseminate mass information on disk to various commands and activities.

V. PROPOSED DOCUMENT STORAGE AND RETRIEVAL SYSTEM

Chapters I and II discuss some of the inefficiencies found in the manual document storage and retrieval system aboard Navy ships. Chapter II further describes the functional elements of what we believe constitutes an optimum document storage and retrieval system, and lists some alternatives based on current document storage technologies. Chapters III and IV discuss these recent technologies in detail, and compare the advantages and disadvantages of each. This chapter discusses how the ship can overcome many of the manual filing inefficiencies by using state-of-the-art technology. Specifically, we describe what we think comprises the *optimum* document storage and retrieval system for shipboard issue and receipt documents.

A. SYSTEM CONFIGURATION AND FEATURES

Based on the functional description and the recent technological developments discussed earlier, we have selected a PC-based optical document storage and retrieval system. This system configuration consists of the following components:

1. AT class personal computer system with 1 MB main memory, 20-40 MB hard disk, floppy disk drive, computer monitor with minimum resolution of 200 DPI, keyboard, raster

image processor board, omnifont character recognition board, and barcode recognition board.

2. WORM optical storage disk drive that uses 5.25 in. removable disk cartridges.

3. Optical document scanner capable of omnifont character recognition.

4. Laser printer.

5. Indexing, storage, and retrieval application software.

The optical storage and retrieval system should have the following basic features:

1. The system will optically scan the documents using the laser scanner, digitize the document images, and store the images on an optical disk.

2. The system will have the capability to store receipt and issue documents on a daily basis aboard ship. The image files must be permanent, so the capability to easily erase images from the optical disk should not exist.

3. The laser scanner should have the capability to automatically (without operator intervention) scan a batch of approximately 50 documents at a time.

4. The system should have the capability to automatically index the documents. Therefore, the system must be able to read the requisition number and NSN *characters* (for non-barcoded documents) or the equivalent *bar codes* (for barcoded documents).

5. The system should index documents by requisition number and NSN. This will allow personnel to *retrieve* documents by document number or NSN.

6. The system must compensate for unreadable characters or bar codes. As an example, after a batch is scanned, have the computer display those documents on the monitor whose characters or bar codes could not be read by the recognition device. The index information could be copied off the monitor or document hard copy and entered via the keyboard.

7. The system must have the capability to store three fiscal years worth of documents.

8. The system must have the capability for file backup.
9. Shipboard personnel should be able to perform some hardware maintenance, as is currently done on the ship's copiers. This is especially crucial when the ship is at sea.

We considered designing the system with the capability to read pertinent information on the receipt document during scanning, and enter the information to SUADPS records via direct line or floppy disk. This would eliminate the need to scan receipt documents with portable bar code readers or to type the document index numbers in by hand. We decided against this for the following reason.

As soon as material is received aboard ship, the receipt information should immediately be input to SUADPS to decrease the chance of information loss. Entering the information via the laser scanner would require pulling a copy of all receipt documents from the material as soon as it arrives on the ship, and scanning these documents just for the receipt information. Input to SUADPS should not wait for signed DTO documents or stock documents with confirmed storage information because the chance of losing the document increases. Later, the receipt copies with the required signatures and storage information would have to be re-scanned to record this additional information on the optical disk. Therefore, input to SUADPS via the laser scanner would still require scanning each document twice, with no real benefit over the portable bar code scanning process. Actually, the scanner input process would probably be more difficult because the recognition device would have trouble reading hand written locations and receipt quantities.

We believe the receipt information should still be consolidated and input to SUADPS via the portable bar code readers. The laser scanner should only scan documents bearing the customer and storekeeper signatures and storage information. Therefore, there is no need to have the laser scanner read any of the receipt information, except the requisition number and NSN which are used for indexing purposes.

B. SYSTEM HARDWARE AND SOFTWARE ANALYSIS

1. Personal Computer-based Electronic Imaging System

The electronic document imaging system proposed in this thesis provides a computerized approach to document storage and retrieval. The system uses a microcomputer and related database management software to automatically index and retrieve receipt and issue documents aboard NSF ships.

To function as an effective indexing and retrieval system, this PC-based equipment configuration should include a CPU with an 80286 or 80386 microprocessor board. These boards operate at a much faster clock speed, typically 8 to

30 MHz, compared to the 8088 microprocessors installed in the older PC/XT models which run at 4.77 MHz. The 80386 word size is also twice as large as that of an 8088 or 80286 microprocessor. With larger word size and faster clock speed, the 80286 and 80386 microprocessors can execute the most demanding data manipulation requirements tasked on any PC-based document storage and retrieval system more quickly than the older 8086 and 8088 microprocessors. Chapter III discusses the characteristics found in various microprocessor boards. Most PC/AT computers aboard Navy ships already have these microprocessor boards installed.

The imaging system must be supported by recognition and raster processors that would allow a user to simultaneously scan, index and store a document image. An optical scanner is required to scan documents for indexing and storage, a magnetic hard disk to store index data, an optical disk to store scanned images, a video display terminal (monitor) to view scanned and retrieved images, and a laser printer to provide a hard copy of digitized document images. These peripheral devices have been described in detail in Chapter IV.

Our recommendation to use a PC-based electronic imaging system is based on several factors:

1. NSF ships have PCs on board. All three ships we visited on the West Coast (one aircraft carrier and two submarine tenders) have a PC in the Stock Control office. Depending on how much usage of these existing PCs for

various word processing and database management applications, they can be used to support a shipboard electronic imaging system. Most PCs are the Zenith Model Z-248, a PC/AT compatible computer with an Intel 80286 microprocessor board. Most of them are equipped with at least a 20 megabyte Winchester hard disk and an EGA monitor for color display.

With some modifications in configuration (installing Raster Image Processor and Optical Character Recognition boards), these "286 platforms" or AT class machines can perform very effectively in document indexing and retrieval applications.

It is much easier for ships to procure peripheral devices and software associated with a storage and retrieval system if they already have a compatible PC/AT with a monitor and an internal hard disk.

2. The ships need a "real-time" system. With current manning levels, the ship's crew have more than enough difficulty in meeting information filing and storage requirements. Any storage and retrieval system which requires several procedures and steps before attaining a final product would only add to the current heavy burden.

   Although a computer aided storage and retrieval systems using microfilm technology have been proven to work in a shipboard environment, specifically aboard a submarine tender on the West Coast, we consider its disadvantages outweigh its benefits. This shipboard microfilm system uses a planetary camera which is sensitive to light. An imprecise adjustment of the camera lens' aperture opening will produce an unacceptable copy of the original document. Furthermore, the microfilm-based system requires film development - an intricate process which can only be efficiently performed in a photographic laboratory, outside of the supply department's control. Based on these significant drawbacks, plus the various other disadvantages discussed in Chapter III, we did not consider proposing a microfilm-based imaging system for shipboard use. Due to time constraints placed on us to complete this thesis, we were unable to perform a cost-benefit analysis on a shipboard microfilm system.

3. Space aboard Navy ships is a precious commodity. Space availability also affects the crew's morale and productivity. A storage and retrieval system that is

bulky and takes up much space is counter-productive to the paperwork reduction goal on Navy ships.

2. Components and Peripheral Devices

a. Storage of Index Information

(1) Magnetic Hard Disk. Since magnetic hard disks are cheap, highly reliable and offer faster access time than any other type of storage media, we recommend its use for storing index data.

Disk storage requirements for index data depend on a variety of application characteristics, including the number of documents to be indexed, the number of index categories used, and the number of characters in the fields. Approximate storage requirements can be calculated using the following formula:

$$S = [D \times (F1 + F2 + ... + Fn)]$$

where:

S = the disk storage requirement in bytes;

D = the number of documents to be indexed;

F = the number of characters in a field for each field in the database.

We can use this formula to calculate the index storage requirements of aircraft carriers and submarine tenders:

D = 140,000 issue and receipt documents. This figure was derived from the time and motion analysis shown in

Appendix D conducted aboard an aircraft carrier and two submarine tenders.

F1 = 15 characters in a Requisition number (i.e. R2013290010001A for a partial receipt document);

F2 = 9 characters in a NIIN (i.e. 011800982);

F3 = 5 characters in the pointer field (image address on optical disk.

$$S = [140{,}000\ (15 + 9 + 5)]$$

$$= 4{,}060{,}000 \text{ bytes or } 4.06 \text{ MB}$$

Using the parameters in the formula given above, the calculation yields an approximate storage requirement of 4.06 MB per year. Multiplying the yearly requirement by 3 in order to satisfy the three fiscal year filing requirement, yields an approximate storage requirement of 12.2 MB. These calculations do not include disk storage space required for the PC's operating system, database management software, and any other software applications residing in the PC. Based on these results, a 40 MB or larger internal hard disk is recommended to support an imaging system.

Storage capacity aside, average access times for hard disk subsystems designed for PC configurations range between 15 and 85 ms. The faster disk drives - those with access times less than 30 ms - are strongly recommended. A Seagate ST series, 40 MB internal hard disk with 28 ms access time for PC/AT computers costs approximately $300.

Most PC/AT computers aboard Navy ships are already configured with a 20 or 40 MB hard disk. Depending on their current usage, these microcomputers may be able to support the indexing and retrieval volume requirements of an optical imaging system plus other database management and word processing software applications used by the ship's crew. An existing hard disk can be replaced if it has insufficient storage capacity to support an optical imaging system.

(2) Optical Storage Device. While document images can be stored on any computer compatible medium, electronic data images require substantial amounts of machine-readable storage space. As a result, they are typically recorded on high-capacity optical disks. But which type of optical storage medium can be best applied to support the proposed shipboard optical storage and retrieval system? We initially considered three types: CD-ROM, WORM, and Erasable Optical media. Figure 5-1 provides a summary of the uses of optical storage technologies [Ref. 26].

We selected the 5.25" WORM optical disk medium because it has the following characteristics:

1. Real-Time Document Indexing and Storage. This feature allows the user to simultaneously scan and index the document into the imaging system. Once indexed and stored, the document can be thrown away. All further references to the scanned document are then performed using the indexed data to retrieve the image, display it on a monitor, or print a copy on a laser printer.

	Read-Only		Write-Once DRAW, WORM, WOODS, ODD	Erasable
When to Consider	**Videodisc**	**Compact Disc**		
When there is a need for . . .	Mass delivery of prepared multi-media information	Mass distribution of data bases, application & operating system software	Mass storage of digital data and images	Individual storage digital data
Criteria for Use				
When user population is . . .	Large and geographically dispersed	Large and geographically dispersed	In discrete locations	In discrete locations
When the data is . . .	Multimedia meterial	Data bases, application software, operating system software	Documents, records, maps, transactions, logs, operating system software	Record and update intermittently
When the situation calls for . . .	Individual or group training, practice, or information gathering	Individual retrieval manipulation of data or application software	Mass storage and retrieval of permanently stored data	Mass storage and individual retrieval of permanently stored data
When data is needed for the successful completion of . . .	Processes, procedures, problem-solving, decision-making	Data searches and computer programs	Document retrieval and manipulation	Data retrieval and manipulation
When storage requirements call for . . .	54,000 individual images —or— 30 minutes of full motion video —or— combinations of the above with two audio channels	60 plus minutes of digital audio —or— 550 MB of digital data —or— 60,000 digitized images —or— 70 minutes of full-motion digital video —or— combinations of the above	From 100 to 6,000 MB of digitized text and images	From 100 MB for for use as an electronic scratch pad

Figure 5-1. Uses of Optical Storage Technologies

Source: Association for Information and Image Management, Silver Spring, Maryland, 1988.

2. Permanence of Stored Data. Data stored on a WORM disk is protected against nearly any type of loss or damage short of physical destruction of the storage media. Since information is burned into a WORM disk with a laser, data cannot be accidentally erased or damaged through static electricity, magnetic fields or other environmental factors. It also provides an audit trail that cannot easily be forged. A recent Department of Justice decision allowing the Internal Revenue Service (IRS) to store all its tax files in WORM disks, can be attributed to this important feature of WORM technology [Ref. 27].

3. Storage Capacity. WORM storage media is considered the most efficient and least expensive form of real-time data storage. Data storage capacities per 5.25" cartridge range from 230 MB to 1.2 GB. Using the data provided by CACI computer engineers, it takes approximately 32 KB of storage space to store the image of a regular receipt document (DD Form 1348-1) at 300 DPI image resolution. This means that a user can store approximately 25,000 receipt and issue documents using an 800 MB 5.25" optical disk cartridge.

4. Removability and Transportability. WORM cartridges are compact and removable. This feature allows the user (Stock Control Division) to copy stored data into another cartridge. For example, when a Submarine Tender goes to sea, the repair and supply functions in support of tended submarines in the tender's homeport continue. These functions are accomplished in designated T-sheds and temporary mobile houses located pierside by tender personnel who remain in port. The indexing and storage of DTO receipts can continue without interruption only if the PC-based imaging system is transferred to the tender's Supply Department site ashore. This would preclude the buildup of receipt documents that, at present, occurs whenever submarine tenders go to sea.

LaserStor Optical drive's specifications are:

1. Price - $4,000 for a single drive unit and $6,000 for a two drive unit.

2. Disk Cartridge - $150 for 800 megabyte capacity.

3. System Interface - SCSI.

4. Operating Systems - DOS 3.0 to 3.31, UNIX.
5. Network Operating Systems - IBM PC/LAN, Novell NetWare, 3Com 3+.
6. Data Transfer Rate - 2.78 Mbits/second. Average Seek Time - 108 ms.

b. Computer Monitor

Most document indexing and retrieval systems will be adequately served by a monochrome video monitor with regular alpha-numeric display capabilities. Few database management programs make effective use of color or graphic displays.

A high resolution monitor (> 500 DPI) is not required to view the image of receipt and issue documents. Based on our observation, the 200 DPI monochrome monitor used aboard a submarine tender on the West Coast provided sufficient clarity to view all the information printed on a receipt and issue document. The PC/AT computers aboard Navy ships were procured with either a regular 12" monochrome monitor or with a 13" color enhanced graphics adapter (EGA) monitor. Both types of monitors are available from a General Services Administration (GSA) contract for ADP equipment awarded to Zenith in the mid-1980s.

c. Producing Digitized Images of Documents

In the typical turnkey equipment configuration, input devices include a desktop scanner for document digitization. While available scanners share similar operational characteristics described earlier, differences in input capabilities, resolution, and speed can have a significant impact on the performance of an electronic imaging system.

While some manufacturers offer overhead scanners that scan documents positioned face up on a copyboard in the manner similar to many planetary microfilm cameras, most optical imaging systems employ flat-bed models of copier-like design. With such scanners, documents are inserted face down into a transport mechanism which automatically moves them past a scanning array. To minimize operator involvement, most models are equipped with multi-page document feeders capable of holding up to 50 documents.

In choosing the optical scanner suitable for shipboard use, we used cost, size, and scanner capabilities as our selection criteria. Using these criteria, we were able to narrow our selection to portable desktop optical scanners with an automatic document feeder. A portable desktop scanner does not take up a lot of space. The automatic document feeder option will significantly reduce the time it takes to scan multiple documents. Finally, portable desktop scanners are much less expensive than comparable full-size scanners.

In our search for a shipboard scanner capable of supporting a PC-based optical imaging system, we looked at three desktop scanner models in order to compare cost, size, and capabilities. The models include:

(1) KURZWEIL DISCOVER 7320 MODEL 30. Key features include an automatic document feeder which holds up to 30 documents; selectable image scan resolution up to 300 DPI; serves as an input device for OCR and Raster imaging to capture both text and graphics; text recognition of characters 8-24 point in size; scan rate of 4-6 pages per minute using a 8.5" x 11" document; weighs 20 lbs; and measures 15.2" wide x 19.3" deep x 5" high. The scanner costs approximately $15,000.

(2) WANG MODEL SC4000. Key features include a single or double-side copy; automatic document feeder which holds up to 50 documents; selectable scan image resolution up to 400 DPI; automatic image exposure control; uses OCR as recognition device; scans document size up to 11" x 17"; weighs 74 lbs; and measures 26" wide x 25" deep x 5.5" high. This scanner costs approximately $29,000 using existing GSA contract.

(3) FUJITSU MODEL M3095E. Key features include a fast scan rate of 2.1-2.3 seconds using a full size document 8.5" x 11"; multiple image resolutions of 200, 240, 300, and 400 DPI allowing the operator to choose the level of quality and scan speed; automatic document feeder which holds up to 50 documents; input device for OCR, CAD and Raster imaging;

weighs 46 lbs; and measures 25" wide x 19" deep x 6.5" high. The scanner costs approximately $6,000.

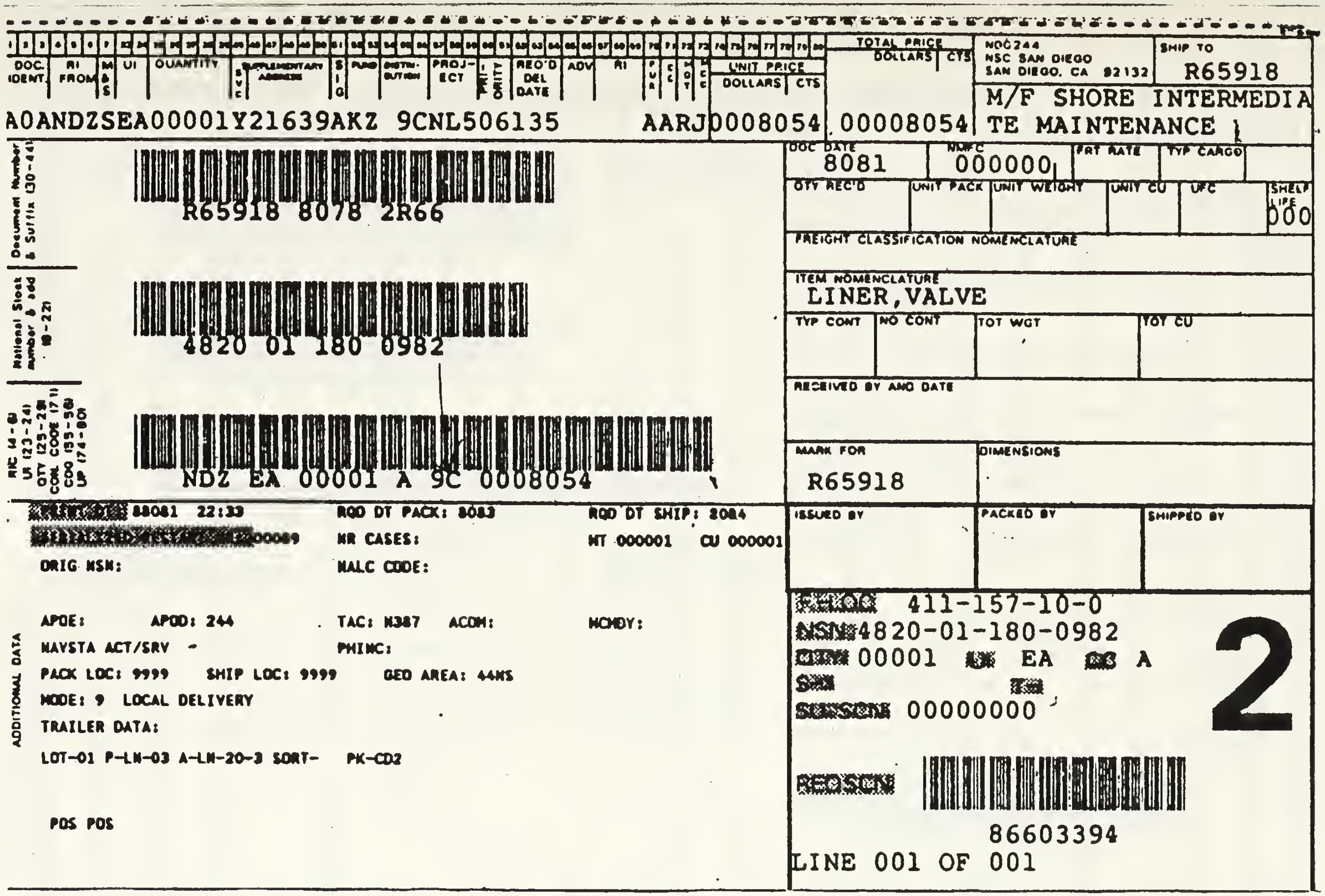
No in-depth evaluation was performed to determine the operational reliability and maintainability of the mentioned optical scanners.

d. Printing Stored Document Images

With cost, size, and capabilities in mind, we looked at several printer models, both dot-matrix and laser, that can produce hardcopy output of document images stored in optical disks. As part of the time and motion analysis we conducted aboard three ships, we printed a copy of a standard 1348-1 receipt document using a dot-matrix printer (ALPS-2000). It took approximately 10 minutes from the print execute command to the time printing was completed to reproduce the image of the receipt document. Although the image reproduced is acceptable (see Fig. 5-2), the printing time is unacceptable.

Most ships use dot-matrix printers with their existing microcomputers. They are either 9-pin or 24-pin printers procured under GSA contract. Most models are the EPSON FX-286e, FX-86e, and ALPS-2000 series.

Using a CACI Inc. optical document imaging system prototype called "Ultra Retrieve" (Version 2), we printed several copies of 1348-1 receipt documents. The system used a Canon model LBP-8 II laser printer. We were able to print


DOC IDENT | RI FROM | M & S | UI | QUANTITY | SUPPLEMENTARY ADDRESS | S I G | FUND | DISTRIBUTION | PROJECT | PRIORITY | REQ'D DEL DATE | ADV | RI | UNIT PRICE DOLLARS CTS | TOTAL PRICE DOLLARS CTS

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SAN DIEGO, CA 92132

SHIP TO
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A0ANDZSEA00001Y21639AKZ 9CNL506135 AARJ0008054 00008054

M/F SHORE INTERMEDIATE MAINTENANCE

Document Number & Suffix (30-44)
R65918 8078 2R66

National Stock number & add (8-22)
4820 01 180 0982

RIC (4-6) UI (23-24) QTY (25-29) CON CODE (71) COO (55-56) UP (74-80)
NDZ EA 00001 A 9C 0008054

DOC DATE 8081
NMFC 000000
FRT RATE
TYP CARGO
QTY REC'D
UNIT PACK
UNIT WEIGHT
UNIT CU
UFC
SHELF LIFE 000
FREIGHT CLASSIFICATION NOMENCLATURE
ITEM NOMENCLATURE
LINER,VALVE
TYP CONT
NO CONT
TOT WGT
TOT CU
RECEIVED BY AND DATE
MARK FOR
R65918
DIMENSIONS
ISSUED BY
PACKED BY
SHIPPED BY

88081 22:33 RQD DT PACK: 8083 RQD DT SHIP: 8084
00089 NR CASES: WT 000001 CU 000001
ORIG NSN: HALC CODE:

ADDITIONAL DATA
APOE: APOD: 244 TAC: N387 ACOM: NCMDY:
NAVSTA ACT/SRV - PHINC:
PACK LOC: 9999 SHIP LOC: 9999 GEO AREA: 44NS
MODE: 9 LOCAL DELIVERY
TRAILER DATA:
LOT-01 P-LN-03 A-LN-20-3 SORT- PK-CD2

POS POS

411-157-10-0
NSN 4820-01-180-0982
00001 EA A
00000000

REQSCN
86603394
LINE 001 OF 001

2

Figure 5-2. Receipt Document
(Dot Matrix Printer Copy)

Source: USS DIXON (AS-37), San Diego, California, 1989.

an average of 7 receipt documents per minute with high quality resolution (200 DPI) as shown in Figure 5-3.

Due to the superior print quality and print speed, we recommend the laser printer over the dot-matrix printer. With the increasing popularity of laser printers, the prices of several models have been declining. The HP series IID Laser Printers are now available in a GSA schedule for about $1,500. These are proven, high quality, compact, economical and dependable laser printers appropriate for shipboard use.

e. *Raster Image Processor*

The use of a Raster Image Processor board for shipboard PC-based optical imaging system is necessary for image scanning, compression, retrieval, and decompression; and hardcopy printing of documents. In general, an image can be scanned, matched to screen resolution, or compressed and transferred to an optical disk - all within a few milliseconds.

The RIP controller board manufactured by Micro Machines is capable of performing complex image compression and decompression functions at speeds up to 30 full size pages per minute. Its Host Control System (HCS) provides the control necessary to simultaneously scan input document, scale the image to screen resolution, display the scaled image, and transfer the compressed image to an optical disk. The HCS also reads compressed image files from disk, sends them to the RIP

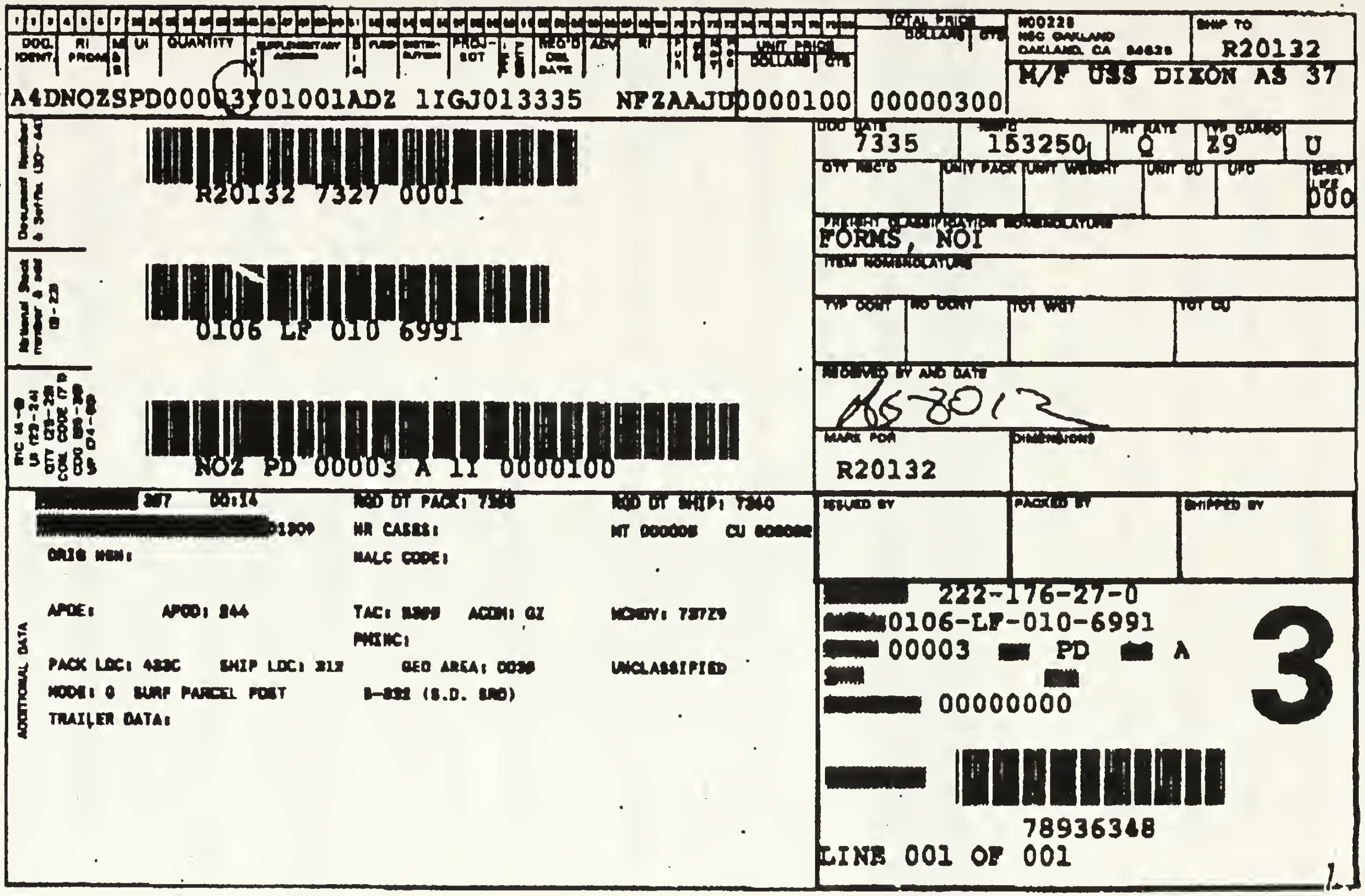
SHIP TO R20132
N00228 NSC OAKLAND OAKLAND, CA 94625
M/F USS DIXON AS 37
A4DNOZSPD00003Y01001ADZ 1IGJ013335 NFZAAJU0000100 00000300
R20132 7327 0001
0106 LF 010 6991
NO2 PD 00003 A 11 0000100
DOC DATE 7335
153250
Q
Z9
U
000
FORMS, NOI
RECEIVED BY AND DATE
MARK FOR R20132
ISSUED BY
PACKED BY
SHIPPED BY
[redacted] 287 00:14
[redacted] 1309
ORIG NSN:
NR CASES:
HALC CODE:
APOD: 244
PACK LOC:
SHIP LOC:
MODE: 0 SURF PARCEL POST
TRAILER DATA:
UNCLASSIFIED
[redacted] 222-176-27-0
[redacted] 0106-LF-010-6991
[redacted] 00003 [redacted] PD [redacted] A
[redacted] 00000000
3
78936348
LINE 001 OF 001
ADDITIONAL DATA
PROTOTYPE ISSUE/RECEIPT DATA FORM

Figure 5-3. Receipt Document
(Laser Printer Copy)

Source: CACI, Inc., San Diego, California, 1989.

for decompression and scaling, and then displays the image on the computer monitor or sends the image to the printer. This RIP board also performs special functions used for matching the scanned image to the computer monitor's screen size.

Due to time constraints, we were unable to evaluate any other RIP boards available in the market. We focused our observation of Micro Machines' RIP board on how it functions in a fully operational PC-based imaging system. This RIP board is installed in CACI's Ultra-Retrieve and WANG's WIIS imaging systems. The RIP board performed as specified by the manufacturer in both optical imaging systems. During the scanning process, a document image was compressed, shown on the monitor and transferred into the optical disk for storage in approximately 2-3 seconds. In the retrieval process, a document image was decompressed and shown on the monitor in approximately 5 seconds.

Since Micro Machines' RIP board is a new product, a market evaluation on its actual performance is not available. Optical imaging system integrators using this product are relying on the manufacturer's warranty. Micro Machines' RIP board specifications are shown in Figure 5-4. The RIP board costs approximately $4,000.

f. Reading Index Information

Within the past five years, there has been a proliferation of recognition devices and their associated

Raster Image Processor

RIP Control System/Standard Functions

Compression/Decompression
CCITT Group 3 1d
CCITT Group 3 2d
CCITT Group 4

Resolution Matching
Filtered scaling (3:1,2:1)
User selectable thresholds

Binary Image Processing
Rotation — Ninety degree units

Scanner Control
Fujitsu 3094a/b

Printer Control
Fujitsu 3072
Canon LBP-CX

RIP Control System — Optional Functions

Halftone Generation
Daisy Wheel Printer Emulation
Tektronix 4014 Vector Rasterization
Binary Image Scale Any (4% to 1000%) —
Nearest Neighbor Algorithm

RIP-SCAN

Processor
RISC type — 5 MIPS on typical image algorithm

General Interface
Centronics Bi-Directional Parallel — up to 30 ppm
RS232 Control Channel

Scanner Interface/Cable Option
Fujitsu 3094a/b, 3095a/b
Canon 220
Ricoh IS30

Laser Interface/Daughter Board Option
Fujitsu 3072 (18 ppm)
Canon LBP-CX (8 ppm)
Ricoh 1060 (6 ppm)

Memory
Socketed Dram SIMMs (no wait states)
standard: 1.5 MegaByte
optional: up to 6 MegaByte

Physical Size
One PLUS PC/AT slot. Only half size cards can be placed beside RIP. The printer daughter card uses the half slot if it is present.

PC bus Interface
8/16 bit data — AT
RIP registers at memory addresses c7000 — c7fff

Figure 5-4. RIP Board Specifications

Source: Micro Machines, Saratoga, California, 1989.

software applications introduced in the market to support various imaging configurations. The most common are bar code and ICR recognition devices. If this two functions are combined into an integrated imaging system, documents can be raster scanned, indexed using bar code and/or printed English characters, and stored on the optical disk in a "hands-off" automated operation. However, based on our discussions with several optical imaging system experts from WANG Laboratories, Bell and Howell, Reference Technologies, Western Office Systems, Calera Recognition Systems, AEDEX Recognition and CACI Inc., no recognition device exists today that is capable of doing image scanning and interpreting bar codes (or performing optical character recognition) in a single operation.

With the advent of LOGMARS, most receipt documents generated within the supply system contain information in barcode format. However, issue documents generated by NSF ships are not bar coded. The latter documents represent approximately 50% of the total number of documents on Supply Department files.

In order to produce issue documents (1348-1) with barcode data, the existing SUADPS supported dot-matrix printers made by Honeywell must be replaced by high-speed laser printers. The Navy Management Systems Support Office's (NAVMASSO) supported software must also be modified in order to change the existing printer escape codes from dot-matrix to a specified laser printer.

Most bar code systems available in the market allow users to use existing storage and retrieval software to accept "scanned" bar code text as index data. For example, AEDEX Corporation of Placentia, California provides a wide assortment of barcode recognition products with full software support that can be used in various imaging applications. Their BCS-225 model is a complete bar code system which accepts bar code data from a wand or a laser scanner. This model is currently used aboard a West Coast submarine tenders. It is capable of automatically discriminating between 11 types of bar code symbologies, which include the 3-of-9 bar code authorized in LOGMARS. The bar code system consists of a bar code system decoder board and a full software package. The BCS-225 interfaces with any PC-based imaging system allowing the scanned data to appear as keyboard input in any applications software without modifications. This PC-based bar code system costs approximately $595.00. Note, however, that there is a great variety of bar code equipment available from more than 46 different manufacturers. A number of these products have features similar to those of the BCS-225. [Ref. 28]

CACI's "Ultra-Retrieve" is a comprehensive document image storage and retrieval system that uses both computer keyboard and bar code recognition to index receipt and issue documents. However, the bar code recognition must be performed as a separate task from image scanning, using a bar code reader to record the index data. Each document must be read with the bar code gun by the operator prior to inserting it into the optical image scanner.

ICR's attraction as a recognition and input technology is obvious. In our proposed optical imaging system, ICR can be used in conjunction with bar code recognition to read and index the Requisition Number and NSN of a non-barcoded document. Given the diversity of supply documents, ICR devices must be able to recognize a wide variety of type styles, including typewriter and computer printer fonts in various sizes. While the character recognition capabilities of omnifont devices have improved significantly since the late 1970s, none of the products on the market are perfect. Characters on extremely wrinkled and perforated documents may be impossible to recognize even by the human eye.

We believe Calera Recognition Systems' "TrueScan" Model E is a scanner recognition device that can work well with most industry desktop scanners. It is an omnifont recognition device with the capability to capture text and graphics data on a document in one pass. Based on our discussions with Calera Recognition Systems technical support engineers, TrueScan can achieve a scanning accuracy of over 99.9%, depending on document input quality. Characters that are impossible to recognize can be flagged for operator examination and identification. Calera's TrueScan specifications are shown in Figure 5-5. This recognition device is approximately $3,900.

When we visited WANG Laboratories in Santa Clara, we were able to observe their WIIS optical imaging system which uses an older version of Calera's TrueScan OCR board. We scanned, indexed and stored several documents on their optical disk. We then retrieved and copied the stored documents and observed no errors in the text and index fields. We also considered the text clarity of the sampled documents to be excellent and easy to read.

Using an ICR board, a bar code recognition board, and a Raster Image Processor (RIP) board, optical scanners can be used to automatically scan, digitize, and index any receipt and issue document for storage and retrieval applications. The integration of these recognition devices into a functional document storage and retrieval system is a highly complex task that can only be accomplished by an expert software systems integrator. Software engineers from CACI, Inc., and TAB Office Products are currently upgrading their PC-based optical imaging systems to combine OCR and bar code recognition in the automatic indexing of documents.

TrueScan Specifications

TrueScan Models

- **Model S** – up to 75 characters per second
- **Model E** – up to 100 characters per second; handles landscape and rotated pages (e.g., fax images)

Features

- Recognized Fonts:
  - — typewritten
  - — typeset
  - — laser print
  - — draft-quality dot-matrix
  - — other computer print
  - — 6 to 28 point
  - — monospace and proportional
- Document Formats Supported (automatically decolumnized):
  - — single and multiple columns
  - — variable column widths
  - — tables
  - — lists
  - — paragraphs
  - — intermixed text and graphics
- Accuracy: Dependent upon quality of input document; optimal documents can achieve 99.9%+
- Skew: ±2 degrees

PC/AT Requirements

- IBM PC/AT, Compaq 286, 386 or 100% compatibles
- MS-DOS™ 3.1 or above
- Memory: 512KB minimum
- 20MB hard disk (3.7MB required)
- Monochrome or color display adaptor and monitor
- 5¼" 1.2MB or 3½" 720K floppy drive

PC/AT Supported Scanners

- AST Turbo Scan
- Canon IX-12, IX-12F (ADF)
- Chinon DS-3000
- Datacopy Jet Reader
- Datacopy Model 730 (ADF)
- Dest PC Scan Plus
- Dest PC Scan 1000/1020
- Dest PC Scan 2000/2020 (ADF)
- Hewlett-Packard ScanJet (ADF)
- Hewlett-Packard ScanJet Plus (ADF)
- Microtek MS-300A (ADF)
  - MS-300C (ADF)
  - MSF-300C
  - MSF-300Q
  - MSF-300G
  - MSF-400G
  - MS-II (ADF)
- Panasonic FX-RS505
- Panasonic FX-RS506 (ADF)
- Princeton Graphics LS-300

(ADF) indicates Automatic Document Feeder support

PS/2 Requirements

- IBM PS/2 with Micro Channel (MCA)
- PC-DOS 3.1 or above
- 20 MB Hard Disk (3.7 MB required)
- VGA Monochrome or Color Display
- 1.44 MB 3½" Disk Drive

PS/2 MCA Supported Scanners

- Canon IX-12, IX-12F (ADF)
- Hewlett-Packard ScanJet (ADF)
- Hewlett-Packard ScanJet Plus (ADF)
- Microtek MS-300A (ADF)
  - MS-300C (ADF)
  - MSF-300C
  - MSF-300Q
  - MSF-300G
  - MSF-400G
  - MS-II (ADF)
- IBM 3119

Optional Daughtercards Available for:

- Canon IX-12
- Hewlett-Packard ScanJet/ScanJet Plus

Supported Output Formats

- **Supported Word Processor Formats**
  - — DCA/RFT
  - — DisplayWrite 2, 3, 4 (DCA/RFT)
  - — EBCDIC
  - — IBM Writing Assistant 1.0
  - — GSA Navy DIF
  - — Microsoft Word 3.0, 3.1, 4.0
  - — Microsoft RTF
  - — MultiMate 3.1, 3.3, 3.6, 3.7
  - — MultiMate Advantage II
  - — OfficeWriter 4.0, 5.0, 6.0
  - — PFS:First Choice 1.0, 2.0
  - — PFS:Professional Write 1.0, 2.0
  - — PFS:Write Version C
  - — PageMaker (Microsoft Word)
  - — Samna (DCA/RFT)
  - — Ventura Publisher (Microsoft Word)
  - — Volkswriter
  - — Volkswriter Deluxe 2.2
  - — Volkswriter 3
  - — WordPerfect 3.0, 4.1, 4.2, 5.0
  - — WordStar 3.3, 3.31, 3.45, 4.0
  - — WordStar 2000 (WordStar 4.0)
  - — XyWrite III
  - — XyWrite III Plus
- **Supported Spreadsheet Formats**
  - — Excel (.XLS)
  - — Lotus 1-2-3
  - — Quattro (.WK1)
- **Supported ASCII Formats**
  - — ASCII
  - — Decolumnized ASCII
  - — PDA Text and Image
- **Supported Image Formats**
  - — PageMaker (TIFF)
  - — PC Paintbrush
  - — PCX
  - — PDA (CCITT Group 4 compressed images)
  - — TIFF Uncompressed
  - — TIFF Modified Group 3
  - — TIFF Packbits
  - — Ventura Publisher (PCX)

Supported Facsimile Cards

- AT&T Fax Connection (Page Power)
- Datacopy Microfax
- Gammalink Gammafax
- Intel Communication Co-Processor
- Panasonic Fax Partner
- Spectrafax The FAXCARD
- Others 200x200 dpi fax images (fine mode) in TIFF, PCX and DCX formats

Calera is a trademark of Calera Recognition Systems, Inc.

TrueScan, Compound Document Processor, Desktop Recognition, Recognition Server, CDP and PDA are trademarks of Calera Recognition Systems, Inc.

Other products are trademarks of their respective holders.

These specifications are subject to verification acceptance by the customer, utilizing standard Calera document test sets, and are subject to change without notice.

Additional formats will be supported: contact your sales representative or Calera for details.

Figure 5-5. True Scan Specifications

Source: Calera Recognition Systems, Inc., Santa Clara, California, 1989.

g. Software to Control Image Storage, Retrieval and Printing

Any optical imaging system, whether the system is based on a mainframe, minicomputer or microcomputer, includes a CPU, monitor, keyboard, magnetic disk storage for index data, optical disk for image storage, a printer, a scanner, device drivers, systems diagnostics, and application software. Systems vary in their image enhancement and display capabilities, data compression algorithms, error correction, quality control, and ability to operate within various operating systems. The software used ties all of these different peripheral devices and components together into an integrated, functional system.

Software systems integrators have been increasingly motivated to enhance the functions of their optical imaging systems and components. Software applications and hardware interface programs are constantly being modified and improved. Write-once optical imaging systems based on real time input are fast becoming an end-user standard [Ref. 29]. Various software products are now available to support PC-based electronic imaging systems. Figure 5-6 shows a typical PC-based electronic imaging system.

Designed as self-contained solutions to commonly encountered records management problems aboard NSF ships, PC-based optical imaging systems with appropriate application

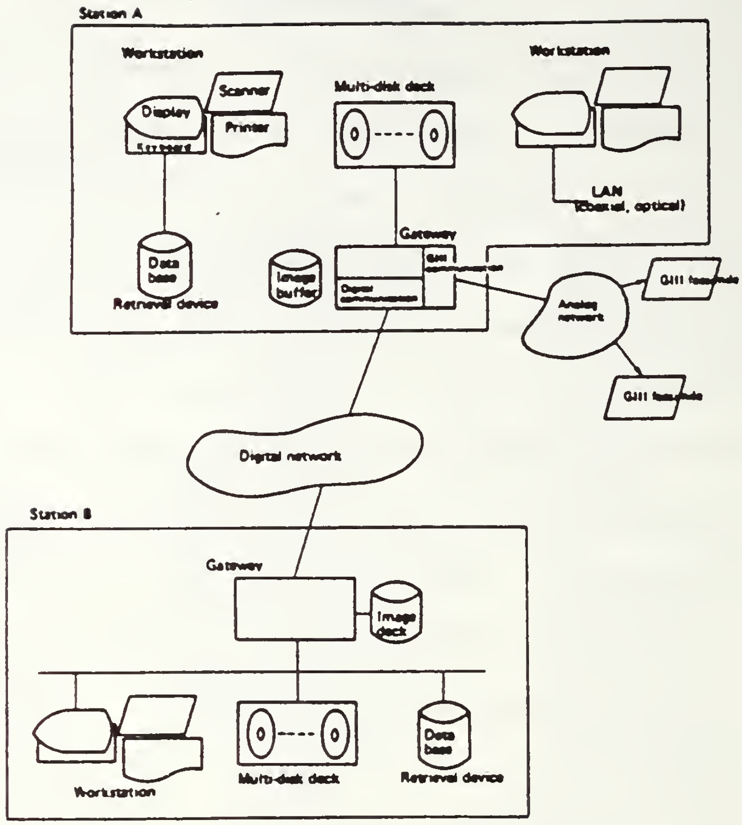

Figure 5-6. Networking an Electronic Filing System
Source: Association for Information and Image Management, Silver Spring, Maryland, 1989.

software can be used to create, maintain, manipulate, and retrieve indexes to documents stored on optical disks. Although document scanners, optical disk drives, and other components of an optical imaging system can be purchased separately, their integration into an effective operational system requires software engineering expertise that is outside of the basic training provided to Navy Data Processing technicians.

We looked at various text and retrieval software packages available in today's electronic document imaging market. We were unable to find one that supports a PC-based optical imaging system that integrates the functions of its key peripheral devices (i.e. computer CPU, optical scanner, WORM drive, and laser printer), and also allows the user to automatically index the document for later retrieval using bar codes and/or OCR.

Some of the software applications we looked at include:

1. TAB Products' Series 2000 Laser-Optic Filing System
2. KOFAX Image Processing Platform (KIPP)
3. Multimax Image Management System (MIMS)
4. Reference Technology Inc. CD-Forms-1 with modification to allow use of WORM optical drive
5. WANG's Integrated Image Systems (WIIS)
6. Bell and Howell's Data Search Filing System
7. CACI's Ultra-Retrieve

All of these software applications come with indexing functions that enable a user to build an index of scanned documents. With the exception of WANG's WIIS and CACI's Ultra-Retrieve, these software applications require the input of index data via computer keyboard.

The latest version of CACI's Ultra-Retrieve allows the user to input document index data through keyboard entry or by using a separate barcode scanner. The image capture and index data input requires two steps. The first step consists of getting the index data using the bar code scanner. The second step involves scanning the document to store the bit-mapped image on the optical disk.

We believe WANG's WIIS system is also a comprehensive software package that uses ICR for text and index recognition. However, this imaging system uses an outdated OCR device with limited text and character font recognition capabilities. The system performed well when we scanned and indexed documents with perfectly aligned characters inside designated fields. When we scanned and indexed a receipt document (DD Form 1348-1), the system failed to recognize the alpha-numeric characters specified in the document number and NSN fields. WANG's technical representative explained that WIIS' OCR device cannot recognize printed characters touching barcodes or lines on the form. The WIIS system, which includes software maintenance support, costs about $39,000.

Unable to find what we consider an optimal application software package to support a shipboard PC-based optical imaging system, we discussed with CACI's software integrators the possibility of modifying the Ultra-Retrieve software and hardware configuration so documents could be automatically indexed during the scanning process. CACI software experts believe they can accomplish this. They expect to complete the software modification by January 1990. The proposed system should be able to interface both bar code and ICR recognition devices with a desktop scanner to allow automatic indexing of receipt and issue documents. Documents with bar codes will be simultaneously scanned and indexed using the barcoded requisition number and NSN data. Documents without bar codes will also be simultaneously scanned and indexed using requisition number and NSN data located in pre-designated fields on the document. Indexing documents with unreadable index fields will be performed by manual keyboard entry.

We are optimistic that CACI's software engineers will be successful in integrating the use of the most technologically advanced OCR and bar code recognition devices in their Ultra-Retrieve system. Once successfully accomplished, this system would almost eliminate the manual indexing process performed by sailors on NSF ships. The latest version (Version 2) of CACI's Ultra-Retrieve is currently installed on 14 NSF ships. The software package costs $5,350.

3. Maintenance and Reliability

Table 5-1 contains a summary list of our proposed document storage and retrieval system, including hardware components, peripherals, and software. All shipboard microcomputers and monitors are under a scheduled Preventive Maintenance System (PMS) performed by Navy Data Systems

TABLE 5-1
Proposed Document Storage and Retrieval System
Hardware Components and Software

Components	Recommended Manufacturer	Estimated Unit Cost	Warranty Period	Reliability	Level of Maintenance
CPU/keyboard	Zenith	$2,800	12 months	Not available	Shipboard PMS, replace boards, simple diagnostics
EGA Monitor	Zenith	550	12 months	25,000 hours MTFB	Shipboard PMS, replace boards, power supply
Optical Drive 800 MB	Storage Dimensions	6,000	12 months MTBF	30,000 hours	replace defective drives when required
Bar Code Board	AEDEX	1,500	12 months	Not available	replace as required
Laser Printer	Hewlett Packard	2,350	12 months	40,000 hours MTBF	replace toner cartridge after 4,000 copies
RIP Board	Micro Machines	4,000	12 months	25,000 hours MTFB	replace as required
OCR Board	Calera Recognition	3,900	12 months	Not available	replace as required
Magnetic Hard Drive 40 MB	Seagate	300	90 days	70,000 hours MTFB	replace as required
Application Software	CACI, Inc.	6,500	16 hours training and installation	Not available	vendor maintenance

Technicians (DS). The PMS requires quarterly electrical checks, disk drive alignment, cleaning of internal components, cleaning of keyboards, and monitor screen adjustments.

The Naval Regional Data Automation Center (NARDAC) and Ship's Intermediate Maintenance Activity in San Diego are conducting scheduled training for ship computer technicians on how to perform Zenith microcomputer diagnostics to identify and replace defective and broken components. They also provide the ships with a list of recommended Zenith PC repair parts that can be procured as ready spares. The list include power supply for the PC and monitor, logic board, memory board, floppy drive, magnetic drive, video board, and system board.

There are currently no shipboard preventive maintenance programs written to support laser scanners, laser printers, and optical drives. However, CACI and Zenith Data Systems offer annual service maintenance for their equipments and software beyond the warranty period. Information on component reliability was provided by the manufacturer when available.

C. SYSTEM OPERATING PROCEDURES

1. Document Filing

Issue and receipt documents no longer have to be physically sorted in requisition number sequence, but some minimal document preparation will still be required. Ripped or crumpled documents should be separated from undamaged ones because they may have trouble feeding through the automatic document feeder. Also, any documents that have smudged bar codes, requisition numbers, or NSN characters should be separated. These documents will require manual feed or indexing via the computer keyboard. Bar coded documents will most likely have to be separated from non-barcoded documents.

When the documents are ready to be scanned, the sailor (operator) will take the documents to the optical storage and retrieval system. First, the operator will power-up the system hardware, and enter all required information such as the current date, user ID, password, and commands to activate the filing system programs. The commands will be totally dependent upon the application software used. The time required to get the system ready should take two minutes or less.

When the system is ready to accept documents, the operator will place a batch of about 50 documents in the scanner's hopper. Then the operator presses a key to commence scanning. The scanner will automatically feed a document to the scanning area, scan the document, and send the image to the optical disk where it is permanently stored. As the image passes through the computer's character recognition device, both the requisition number and the NSN are read, converted to data form, and recorded on the computer's magnetic disk. These two numbers, along with the pointer number giving the image location on the optical disk, are recorded separately to form the index that operators will use to retrieve document images in the future.

If documents get stuck in the automatic feeder, the computer should audibly prompt the operator and display a message on the screen. If the system could not read the requisition number or NSN for indexing, the computer should similarly prompt the operator to enter the index numbers via the keyboard.

Torn or smudged documents (separated during document preparation) cannot be run through the automatic feeder. They must be manually placed face down on the scanning area. For smudged documents, the operator must input the requisition number and NSN via the computer keyboard.

Once the paper documents are scanned, the operator places them in a temporary holding file until the newly stored images are copied to the backup optical disks. The operators should perform the backup procedure daily. After disk backup, the paper documents can be discarded (burned in the ships incinerator).

2. Document Retrieval

Supply personnel continually retrieve source documents to help them correct inventory and financial discrepancies.

When dealing with financial discrepancies, such as working on the C&H Listing, or doing requisition file maintenance, the sailor has the unique requisition number of the document he wishes to retrieve. When dealing with inventory discrepancies, the sailor only has an NSN with which to conduct research. Therefore, the operators should have the capability to retrieve documents by requisition number or NSN. Otherwise, the research process will require producing special SUADPS reports that list all receipt or issue transactions in NSN sequence. The researcher would first have to look up the NSN's on the report, find the corresponding requisition number, and then retrieve the document by the requisition number. Not only would this procedure require extra retrieval time, the computer report only contains the transactions input before the report was printed, not the most recent transactions.

Documents will be retrieved two ways -- they will be displayed on the computer monitor or they will be printed if a hard copy is needed. To retrieve a document, the operator first turns on the power to the system hardware, and then enters the preliminary information such as user ID, password, and commands to activate the retrieval program. Then the operator tells the computer what type of documents he wants retrieved, issue or receipt documents. Next the computer should prompt the operator to enter the index numbers, either the requisition numbers of the documents, or the NSN's associated with the documents. If the operator wants to retrieve documents by NSN, he should have the option to give a range of julian dates corresponding to the potential requisition numbers associated with the particular NSN. This will limit the number of retrieved documents to a given range of issue or receipt dates, instead of retrieving all documents with the attached NSN. Of course the option to print all documents with a certain NSN should be available. After entering all index numbers, the computer should print all documents in series, or display one document at a time on the monitor. Displayed documents should not change until directed by the operator.

D. SYSTEM BENEFITS AND COST ANALYSIS

Now that we have proposed what we think is the best alternative to the manual filing system, we must answer the question -- Should the Navy invest in the proposed automated document storage and retrieval system? In the first part of this section we discuss the benefits the ships will realize by implementing the proposed PC-based document storage and retrieval system. Then we compare the costs of manual filing and retrieval to the costs of a PC-based filing and retrieval system.

1. Benefit Summary

The ships will realize the following benefits by installing the proposed system.

a. Reduced Labor Time

Appendix B contains the results of our time and motion analysis. To file 100 documents manually took 75 minutes on average, or 45 seconds per document. This represents dedicated filing time under controlled conditions. Under normal conditions the sailors are more apt to take more time due to frequent breaks or to welcome interruptions due to the monotony of filing. We estimate it will only take 35 minutes to file 100 documents with the proposed automated system, or 19 seconds per document. Of the 35 minutes, 25 minutes will actually be spent by the operator on document preparation and getting the system ready for mechanized filing. The remaining 10 minutes will strictly be machine scanning time.

To retrieve 100 documents manually took 332 minutes on average, or 3.32 minutes per document. Much of this time was spent looking for documents that were either misfiled or not on file, increasing the search time. We estimate it will take only 17 minutes to retrieve 100 documents under the automated system, or 10 seconds per document. The automated system also gives a storekeeper the ability to retrieve a document directly by requisition number or NSN without having to produce any special reports.

b. Reduced Space Requirements

The ships require an average of 23.5 filing cabinets to file the hard copy documents. At 8.7 square feet per cabinet, including the open space required to enable opening the drawers, 204.5 square feet of filing space per ship are required for manual documents. The automated system requires only 15 square feet.

c. Improved File Accuracy

Since filing time is reduced with the automated system, the sailors can easily complete filing jobs on a daily basis. This should eliminate the routine filing backlogs that contribute to lost documents. Since the documents will be put in sequence by the computer, we believe the operator error will be significantly reduced, if not eliminated. Since the records are permanently stored, they cannot be lost or misfiled in the future. When a document is printed for reconciliation research, there is no need to replace it in the file.

d. Improved Inventory and Financial Records

We believe inventory and financial reconciliation procedures will be improved for two primary reasons. First, since file accuracy will be greatly improved, the document images will be available when people need them to correct discrepancies. Second, since document retrieval time is greatly reduced, more time can be spent on identifying and correcting the discrepancies.

e. *Decreased Fire Hazard*

After the documents are copied to disk, they are thrown away, decreasing the fuel for potential shipboard fires.

f. *Increased Morale*

The automated filing system performs one of the sailor's most mundane and time consuming tasks - sorting and filing documents. Therefore he has more time to perform the more beneficial record maintenance and career development tasks. Also, the space the filing cabinets currently occupy can be converted to sailor work space, improving the general work environment.

2. Cost Analysis

Tables 5-2 and 5-3 show the estimated yearly operating costs for the manual and PC-based filing systems, respectively. The estimated yearly savings with the PC-based system amounts to $10,546. The majority of this savings is due to the reduction in filing labor hours with the mechanized system.

The purchase price of a PC-based filing and retrieval system, as shown in Table 5-4, is approximately $33,500. This includes *all* of the necessary hardware and software

TABLE 5-2
MANUAL FILING AND RETRIEVING SYSTEM COSTS

Ave. Nr. documents filed per day [4]	530
Ave filing time per document [5]	.75 min.
Minutes filing per day	397.5
Ave Nr. documents retrieved per day	36
Ave. retrieval time per document	3.32 min.
Minutes retrieving per day	119.52
Total daily minutes filing and retrieving	517.02
Total daily filing and retrieving hours	8.62
Sailor's average hourly pay rate[6]	$8.08
Yearly labor costs[7]	$18,387
Yearly filing cabinet replacement costs (23.5 file cabinets/7 year life)x$515 per cabinet (GSA 1989 catalog price)[8]	1,929
Yearly filing and retrieval costs	$20,318

[4] For derivation of average daily number of documents filed and retrieved, see Appendix C.

[5] For derivation of average document file and retrieval times, see Appendix B.

[6] The annual pay of an E3 with over 3 years of service was used. Annual pay consists of base pay, basic allowance for quarters (BAQ), and basic allowance for subsistence (BAS), using the fiscal year 1989 pay scale. The hourly rate was determined by dividing annual pay by the average number of hours worked per year. Annual pay = $16,810.
Average annual work hours = 40 hours/week X 52 weeks/year = 2080 hours/year.
Hourly rate = $16,810/2080 = $8.08

[7] Yearly labor costs = ($8.08 per hour) X (8.62 hours per day) X (22 days per month filing (From Appendix C)) X (12 months per year) = $18,387.

[8] the number of filing cabinets holding issue and receipt documents on board the aircraft carrier and the submarine tenders were 24 and 23, respectively. The average number equals 23.5. A seven year filing cabinet life is assumed by the authors.

TABLE 5-3
PC-BASED FILE AND RETRIEVAL SYSTEM COSTS[9]

Ave. Nr. documents filed per day	530
Ave filing time per document	.32 min.
Minutes filing per day	169.60
Ave Nr. documents retrieved per day	36
Ave. retrieval time per document	.067
Minutes retrieving per day	2.41
Total daily minutes filing and retrieving	172.01
Total daily filing and retrieving hours	2.87
Sailor's average hourly pay rate	$8.08
Yearly labor costs	$ 6,122
Yearly cost for disk cartridges ($150 x 7)	1,050
Yearly hardware maintenance cost	2,000
Yearly software maintenance cost	500
Yearly printer ink and paper cost	100
Yearly filing and retrieval cost	$ 9,772
Yearly manual system cost	$20,318
Yearly PC-based system cost	- 9,772
Yearly savings with PC-based system compared to manual system	$10,546

TABLE 5-4
PC SYSTEM PURCHASE PRICE

IBM 386 compatible PC, 1 MB RAM, 40 MB hard disk, floppy drive.	2,800
High Resolution (EGA) monitor, with card	550
Optical disk drive, with two 5 1/4" drives	6,000
Desktop laser scanner	5,800
Laser Printer	2,350
RIP board	4,047
OCR board	3,900
Barcode board	1,500
Scanning/indexing application software	6,500
Total purchase price	$33,447

[9] For derivation of estimated file and retrieval times per document, see Appendix D.

components. Some ships may be able to use their existing PC's, reducing the purchase price by about $3350.

Tables 5-5 and 5-6 show the discounted payback period and net present value by investing in the PC-based system. Based on the values in Tables 5-2 to 5-4, 4 years will be required to recover an original investment of $33,500. Over a five year period, the installation of the PC based system has a net present value of $6,477.

This cost analysis is presented to show the potential savings in labor hours and filing cabinet costs, and that these savings can be translated into a quantifiable measure - U.S. dollars. However, we do not foresee an actual, realized savings in labor dollars through a reduction in the ships manning as a result of installing the PC-based system. We expect the labor hours once used for filing will be converted to more productive tasks such as C&H List processing, outstanding requisition file maintenance, and inventory control. As a result, the stock control division should realize an increase in overall customer service performance.

TABLE 5-5
DISCOUNTED PAYBACK PERIOD
(Discount rate = 10%)

	Discounted Net Cash Flows	
Year	Annual	Cumulative
0	(33,500)	(33,500)
1	9,587	(23,913)
2	8,716	(15,197)
3	7,923	(7,274)
4	7,203	(71)
5	6,548	6,477

Payback period = 4.0 + 71/6,548 = 4.01 years.

TABLE 5-6
NET PRESENT VALUE
(Assume 5 year investment period)

System Purchase Price = 33,500
Nominal value of yearly savings - $10,546

Year 1	Year 2	Year 3	Year 4	Year 5
9,587	8,716	7,923	7,203	6,548

NPV = (33,500) + 9,587 + 8,716 + 7,923 + 7,203 + 6,548
= **6,477**

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The value of stored information is in direct proportion to its accessibility. If we cannot find a new cost-effective and efficient system for storing and retrieving receipt and issue documents aboard NSF ships, we will continue to pay heavy penalties imposed by massive paper files in the form of wasted time, money, and personnel.

Although the use of the current version of Ultra Retrieve is an important step towards reducing shipboard paper files, this system still requires a considerable amount of manual intervention in the indexing process. This system requires manual indexing of non-barcoded documents where mistakes could easily occur. We believe the technology is available today that would allow the creation of a fully integrated PC-based optical imaging system using both ICR and bar code recognition devices to index the documents.

Several leading industry experts in optical imaging share our views. Software systems integrators at Reference Technology Inc. of Boulder, Colorado believe they could develop a software to support this modular approach given the right development funding. TAB Products Company of Palo Alto, California is currently in the process of upgrading their

Laser-Optic PC-based filing system to allow automatic indexing of records using an ICR recognition device. CACI,Inc. of Fairfax, Virginia is also in the process of developing modifications to their Ultra Retrieve system that will fully integrate ICR and bar code document indexing.

The economic analysis presented in Chapter V contains quantitative and subjective parts. The benefits to be gained by using a shipboard PC-based optical storage and retrieval system are, to a large extent, not directly quantifiable.

The technological advances in the field of computerized record management has been rapid. New and enhanced versions of every component of an optical imaging system are introduced in the market almost yearly. However, we see no reason to wait any longer for something better to be introduced. The Navy should use available technology in optical imaging if so it can realize the potential benefits discussed in Chapter V.

B. RECOMMENDATIONS

Navy aircraft carrier and submarine tender type commander and ship representatives should review various document storage and retrieval systems to determine if they meet the criteria listed in chapters II and V. The accuracy of the automatic indexing process during document scanning must be scrutinized to see if it is within acceptable standards. If a PC-based document imaging system is found that meets the criteria listed in Chapter V, the document indexing accuracy rate is 90 percent or greater (the accuracy rate used to determine estimated document file and retrieval times in Appendix D), and the system cost is less than or equal to $33,447 (cost used in Table 5-4), then the Navy should procure the system for all aircraft carriers and submarine tenders. The potential yearly savings of $10,546 would pay for the system hardware and software purchase cost within four years. However, as we mentioned in Chapter V, all of the savings would not be realized; the labor savings would equate to an increase in ship's performance. Although the intangible benefits cannot be quantified, they alone may justify purchasing and implementing the PC-based file system.

Further research should be conducted to determine the feasibility of modifying SUADPS to print issue documents with bar coded data. This would simplify the PC-based system, concentrating on bar code recognition instead of having to accommodate both bar code and ICR for automatic document indexing. Bar code recognition is also consistent with the LOGMARS data entry system.

Our proposed document storage and retrieval system can also be used for the following shipboard filing applications:

1. Stock Control Division -- open purchase files, depot level repairable turn-in documents.

2. Disbursing -- disbursement, public, and collection vouchers and payroll documents.

3. Ships Store -- receipt and invoice files.

APPENDIX A

GLOSSARY

Access time-The time required to find, retrieve, and display a piece of recorded information. Access time usually refers to the longest time a storage device requires to get to a piece of information. For many CD ROM drives, access times range from 0.5 to 1.5 sec.

Alphanumeric-Alphabetic and numeric, usually referring to keyboard characters containing both letters and numbers.

Analog-In electronics, a signal that is continuously variable (often expressed as a wave), as opposed to a digital signal which is discretely variable (often expressed as pulses). Analog phenomena in nature include waves, time, temperature, and voltage. These can be expressed digitally by periodically sampling the analog components.

Application software-Programs designed for a specific task, such as word processing or data search and retrieval.

Archival-Readable (and sometimes writable) for a long time; "long means anywhere from five years to more than 100 years depending on the technology. In micrographics, archival is defined by ANSI PH1.43, and it means permanent.

ASCII (American Standard Code for Information Interchange)-A code established by the American Standards Association, ASCII is a standard table of 7-bit digital representations of upper-and lowercase Roman letters, numbers, and special control characters in teletype, computer,and word-processor systems. ASCII is used for alpha-numeric communication by all major software manufacturers except IBM, which uses EBCDIC, a similar code is devised. Since most computer systems use a full byte to send an ASCII character, many hardware and software companies have added their own nonstandard and mutually incompatible codes to the official ASCII 128-character set, extending it to 256 characters.

Bar code-An array of rectangular marks and spaces in a predetermined pattern.

Batch processing-A data-processing method in which all data is gathered and processed or transmitted at one time, involving no interaction with the user.

Bit-A contraction of binary digit, a bit is the smallest piece of data a computer can recognize. A bit is written as either 0 or 1 and represents either the on or off variation of voltage. Data bits are used in combination to form characters; framing bits are used for parity and transmission synchronization in telecommunications and CD ROM.

Bit map-A screen display in which each pixel location corresponds to a unique main memory location accessible by the central processing unit. Also can refer to images intended for display on this type of display system. See also pixel.

Bits per second-A measure of information systems' speed of transmission, usually expressed as baud rate (usually about one bit per second).

Block-An amount of data that is moved or addressed as a single unit. In CD ROM, a block can be 512 B, 1 KB, or 2KB.

Board-Synonymous with circuit board or card. The circuit card that holds the chips and wiring that control either some essential function of the computer's central processor or a peripheral such as CD ROM drive. See also interface.

BPI (bits per inch)-A measure used to express a recording medium's information density.

Buffer-A small part of a computer's memory that temporarily stores data. Buffers can compensate for a difference in data flow rates when transmitting data from one device to another or can hold data likely to be used in the near future.

Byte-An 8-bit unit of digital data. In data processing, a byte often describes one position or one character, because most computer systems use a full byte to store an ASCII character. A byte can have 256 (or 2^8) possible combinations of 8 binary digits.

CAD-Computer aided design.

CAM-Computer aided manufacturing.

CAV (constant angular velocity)-A disk drive mechanism that spins a disk at a constant speed, resulting in the inner disk's tracks' passing the reading mechanism more slowly that do the outer tracks. Sectors on a CAV disk radiate in uniform patterns from the disk's center, so they are smaller at the inner areas, with higher storage density. A floppy disk is a CAV disk. See also CLV.

CCITT-Consulting Committee for International Telephony and Telegraphy, an organization that develops international communication standards. To date, four such standards have been designated:
Group 1: A bit-map raster for use in facsimile transmission of analog signals
Group 2: Huffman run-length code is a one-dimensional means to compress raster files for use in facsimile transmission of analog signals. Instead of storing each pixel, as in Group 1, the Huffman run-length code designates the coding and decoding of a binary transition, i.e., a change from a black pixel to a white pixel.
Group 3: Relative Element Addressing (READ) code is a two dimensional means of compressing 200dpi raster files for use in facsimile transmission of documents. The READ code further enhances the Huffman run-length code by collecting statistics on the length of runs and determining the number of most frequent occurrences. This redundancy reduction technique is possible by digital processing of black and white documents.
Group 4: This standard for digital, high speed 200-400 dpi data transmission is just emerging. Once defined, there no longer will be any requirements for D/A or A/D conversion; the speed of transmission will increase; and the alternative transmission means, such as satellite transmission, will become available.

CD ROM (Compact Disc Read-Only Memory)-A version of the Compact Disc standard intended to store general-purpose digital data for personal computers. Provides 556 MB user capacity at 10^{-13} corrected BER, compared with 635 MB at 10^{-9} for the CD standard. Also known as the Yellow Book standard.

Central processor-The "brain" of the computer, to which all of its parts are linked and where all information processing-instructions, calculations, data manipulation-occurs. Also called the CPU (central processing unit).

Character-One set of symbols that may be arranged in ordered groups to express information.

Clock-In computers, a device that marks time and generates a periodic signal, which controls the timing of all computer processing operations in a synchronous computer.

CLV (constant linear velocity)-A disc drive (such as a CD ROM drive) that rotates the disc at varying speeds, moving data past the optical head at a constant speed. The drive must rotate the disc more slowly as the head moves from the inner tracks toward the outer perimeter. This design allows data to be stored on the disc at a constant linear density, but requires special tracking and sensing devices to slow down the disc as the head rotates. A CD ROM drive's rotational rate ranges from 500 to 200 rpm.

Compact Disc-The trademark name for an injection-molded aluminized disc, 12 cm in diameter, which stores high-density data in microscopic pits that a laser beam can read. Conceived by Phillips and Sony, it was originally designed to store high-fidelity music for which Compact Disc Audio now is a standard format accepted world-wide. Because of its very large data storage capability, the Compact Disc now is used as a text/data medium in electronic publishing (CD ROM).

Compatibility-The extent to which different types of disks can be interpreted by various players or drives. For example, all CD-Digital Audio discs are fully compatible with all CD-Digital Audio players, so any player can read and reproduce music from any disc regardless or its manufacturer.

Compression-1. In the context of digital images, the process of compacting data based on the presence of large white or black areas in printed pages, engineering drawings, or other images. The CCITT digital facsimile standards contain one- and two-dimensional compression/decompression algorithms. 2. Text compression refers to any technique that saves storage space by eliminating gaps, empty fields redundancy, or unnecessary data. All compressed data must be expanded by a reverse operation called decompression.

Compression algorithms-Formulas for condensing data to save storage space. The CCITT Group III and IV standards for digital facsimile contain some of the most successful of these.

Computer graphics-Line drawings, pictures, charts, and graphs created using a computer.

Configuration-An electronic system's composition, particularly its physical components.

CRT (cathode ray tube)-Display mechanism in a television set. The sealed glass tube is filled with low-pressure gas. An electron gun (or guns, in the case of a color monitor) in its neck focuses a narrow beam of electrons that scans the screen, causing its phosphor coating to glow where hit, thus creating an image.

Database-1. A collection of digitally stored information. 2. A collection of data elements within records within files that sometimes relate to other records within other files.

Database management system (DBMS)-A set of programs that organize, store, and retrieve machine-readable information form a computer-maintained database.

Digital-In computing terms, data that is generated as or translated into a series of discrete, fixed values such as digits or other characters. The opposite of digital is analog. Digital information is record in binary notation.

Digitize-To convert analog information into digital data that a computer system can process.

Directory-A structure specifying the exact locations, or addresses, of files on an electronic storage medium (such as floppy disk or CD ROM disc).

Disk operating system (DOS)-A microcomputer software program that controls the flow of data between the system's internal memory and external disks. VMS, MS-DOS, CP/M, and UNIX are widely used operating systems. CD ROM operating systems include Reference Technology's STA/File, TMS's LaserDOS, Digital Equipment Corp.'s Uni-File, and MS-DOS with CD ROM extensions. Most CD ROM operating systems work with the proposed High Sierra Format.

Document-The basic unit of retrievable data within a database. Document size varies; generally, documents should be as small as needed to efficiently index a data base.

Download-The process of loading program data from some storage medium into the computer.

DPI (dots per inch)-A measure of resolution-that is, the number of pixels per inch on a CRT display or scanning device.

Drive-A machine for reading from and , when possible, writing to an electronic data-storage medium (such as disk, tape, or card). The medium can be optical, magnetic, and so forth.

Emulation-Imitation of a computing function by a system not originally designed to perform that function.

Error rate-The ratio comparing the amount of erroneously transmitted information with the total amount sent.

Facsimile (fax)-1. The process by which document images are scanned, transmitted electronically, and reproduced either locally or remotely. 2. The document this process produces.

Field-1. In data structures, the smallest unit stored in a database. For example, in a mailing list, each record would contain one name, street address, city state, and ZIP code; each of these items is a field. 2. In video, a scan of one-half the lines that comprise a single, complete frame on the video screen. Two interlaced fields make up one frame. NTSC systems use a 525-line frame, so each field contains 262.5 lines. In noninterlaced systems, the field and frame are the same.

File-In computing, a set of related information structured in a similar manner accessed under a single name.

File system-A method of organizing data on a disc such that an application program need not be concerned with the physical location or structure of the data.

Flat-bed-A mechanism for holding the original document on a flat, surface. In a flat-bed scanner the document is stationary and the light source moves.

Font-In printing and computerized character generators, the set of characters and special symbols available in one style and size of type.

Formatting-The process of blocking user data and adding information identifying each block. The formatting information includes the data address and synchronization information, and may include error correction check sums and data, as well as a data type specification. The formatting process also creates the directory for all files on the disc.

Frequency-the number of times a signal vibrates within a given period; usually measured in hertz (Hz), or cycles per second.

GB-gigabyte.

Hard disk-An inflexible magnetic disk wit greater storage capacity than a floppy disk. A hard disk is sometimes sealed within a computer to provide a large (often temporary) memory for looking up data from several smaller, handier floppy disks before running a long or complex program. The Winchester disk is one such hard disk.

Hardware-Electrical or mechanical equipment involved in producing, storing, distributing, or receiving electronic signals.

Hardware compatibility-The ability of two differing pieces of equipment to perform with the same software. For example, computers of two manufacturers both might use the same plug-in module, or peripheral device.

Hertz-The standard measure of frequency or bandwidth; 1 hertz is equal to one cycle per second. One kilohertz (kHz) is 103 cycles per second. One megahertz (MHz) is 106 cycles per second. Electronic data-processing equipment operates in time to a clock, performing one act for each cycle of the clock. The faster the clock runs (expressed in hertz), the faster the equipment operates.

High resolution-The degree of resolution (see entry) necessary for a monitor to display clearly readable 80-column text. Computers for professional use normally employ high-resolution monitors, as will the new generation of enhanced TVs due on the market in the late 1980s.

High Sierra Group-An ad hoc standards group set up to establish nominal data format and compatibility for CD ROM. The group, including representatives from the hardware, software, and publishing industries, is named after the Lake Tahoe hotel where it first met in the summer of 1985.

Huffman encoding-A data-compression scheme that uses variable-length codes, choosing the shortest codes for the most frequent values. It is used for one-dimensional data compression in the CCITT Group III digital facsimile standard.

Image-Pictorial information, such as a drawing, graphical data, and satellite photography.

Indexing-The process of building data structures for an electronic data-base that contain the location of each word or other data item. Indexes permit the computer to rapidly locate data without searching through the full body of data. A data item is searchable only if it is indexed.

Intelligent scanner-A term used to denote additional capabilities of the scanning system, such as the ability to recognize characters (OCR), free standing circles, etc. automatically, or to train the system to recognize commonly used patterns or symbols.

Interchangeability-The ability to exchange components of a computer system for different manufacturers' models and still get performance within the system specification. All compact cassettes and cassette recorders are interchangeable, as are Compact Discs and Compact Disc players.

Interface-1. A link between two systems (such as a microcomputer and CD ROM). Generally, an interface links two components or functions that normally would not interact. Both software and hardware can have interfaces. 2. In microcomputers, interface usually describes the circuit board that attaches a particular peripheral device to another microcomputer.

Jukebox-A disc player that can hold and access several discs.

K (K Byte, KB)-Abbreviation for kilobyte, which is 2^{10}, or 1024, bytes. A computer's size often is expressed according to the number of kilobytes of memory it offers, and the number is usually rounded off to the nearest 1000 bytes.

LAN (local area network)-A network of connected electronic devices within a small area such as an office or a building.

Laser (Light Amplification by Stimulated Emission of Radar)-A device that transmits an extremely narrow and coherent beam (separate waves in phase with one another rather than jumbled, as in normal light) of electromagnetic energy in the visible light spectrum.

Machine code-The binary code (the pattern of zeros and ones) instruction set that is the computer's native language. High-level languages such as BASIC or C are ultimately converted into machine code within the computer. Machine code operates faster, using less memory, than high-level languages, and do is extensively used in real-time applications.

Magnetic media-Magnetically sensitive devices for storing and distributing information. Hard disks, floppy disks, compact cassettes, and video cassettes are examples.

Magnetic tape-A recording medium consisting of a thin tape coated with a fine magnetic material. Data is recorded in the form of changing magnetic levels on the tape coating.

Mainframe-A large, expensive, powerful computer intended for centralized application.

Media-Plural of medium (see entry). Media often is misused as though it were singular.

Medium-In computing, a substance or object on which information is stored; usually refers either to the sensitive coating on a writable device or to the device itself (that is, the disk, tape, card and so forth).

Memory-Synonymous with storage capacity (see entry). Any electronic repository for data. The term often is used to describe main or internal memory, in which case it must be distinguished from backup memory. See also Random-Access Memory and Read-Only Memory.

Menu-In an interactive system, a list of options displayed for the user to select from.

Microprocessor-1. An integral piece of hardware, a microchip, which performs the logic functions of a digital computer. 2. A piece of hardware that houses the computing parts of a computer on one circuit board or in one set of integrated circuits. The microprocessor does not contain ports for peripheral devices or memory.

Modem (from MOdulate/DEModulate)-A device for converting information for the computer into signals that ordinary telephone lines can transmit.

Monitor-1. In video, an electronic device similar to a television that receives and displays a nonbroadcast video signal sent across wires within a closed circuit (from, say, a videotape or disc player), but that cannot intercept a broadcast signal. 2. In computing, another name for the computer screen.

OCR (optical character recognition):A method for converting printed characters to machine-readable character codes through an optical sensing device and pattern recognition software.

Outline processing-A data-processing method that enables a user to enter data, then have it processed and output on request. Compare with batch processing.

Operating system-The set of programs that control a computer and its peripherals, dictating which software can be used. The predominant microcomputer operating system is MS-DOS, while larger minicomputers may used UNIX or VMS.

Optical disc-A disc read and/or written by light, generally a laser. Such a disc may store video, audio, or digital data.

Optical media-Optically sensitive devices used to store and distribute information (for example, the Compact Disc or the LaserVision disc).

Optical storage-Storage of information on optically sensitive materials. These optical media (such as the Compact Disc or the LaserVision disc) have very high storage density.

PC-Personal Computer.

Peripheral-Equipment, such as disk drives and printers, that is controlled by a computer but is physically independent of it.

Pit-1. A microscopic depression in the reflective surface of a CD ROM disc. The pattern of pits on the disc represents that data that is stored. The unpitted area between pits is called a land. The tiny laser beam used to read back the data is reflected from the lands, but scattered by the pits. A typical pit is about the size of a bacterium-0.5 by 2.0 microns (millionths of a meter). 2. Broadly used to refer to any type of data-carrying mark in optical media.

Pixel-A picture element in a video display; the minimum raster display element, represented as a point with a specified color or intensity.

Premastering-In CD ROM, a data formatting process performed on each block of user data. The process determines the sector address and adds synchronization information. If the format is to be mode 1,288 bytes of error detection and correction data are calculated and this data is added at the end of each sector to ensure the full recovery of user block data.

Random access-The ability to reach any piece of data on a storage medium in a very short period of time. Random access makes branching, searching, and nonlinear play possible.

Random-Access Memory (RAM)-Semiconductor memory circuits used to store data and programs in information-processing systems.

Raster-The ares that a scanning beam of a CRT illuminates. Also the array of scan lines that cover a display area and depict images, called a raster scan.

Raster Scanner-A process during which a beam moves back and forth over a character or pattern. The reflected light is received/detected, converted from an analog signal to digital code so that the pattern can be analyzed.

Read-To acquire data from one storage device or medium and transfer it to another medium, usually the computer's memory.

Read-Only Memory (ROM)-Semiconductor memory circuits that contain prewritten programs or data. The contents of ROM circuits is permanent, while the content of Random-Access Memory (RAM) circuits is volatile.

Read/write capability-For storage devices,the ability to both write (record) and read (play back) information. Most magnetic devices can write repeatedly, read, erase, and then rewrite. Usually, optical devices are read-only, although some optical discs can be written once but not erased. Erasable optical discs currently are being researched.

Real time-An operating mode under which data is received and processed and the results returned so rapidly that the process appears instantaneous to the user.

Record-A collection of related fields in a database. Each record in a database of company clients might contain such information as the client's name and address, purchasing history, and credit history.

Resolution-The fineness of the detail in a video or computer display screen, measured as a number of discrete elements-dots in a scanner, pixels in a monitor. The higher the number, the higher the resolution and the better the picture.

Scanner-A device that resolves a two-dimensional object, such as a business document, into a stream of bits through raster scanning and quantization. Also called an optical scanner.

Scanning-The process of converting line or character information on source documents to picture elements or pixels.

Software-A set of programs, procedures, and documents concerned with the operation of a data-processing system.

Stand-alone systems-Internally compatible systems that perform their specified functions in conjunction with an operator or user without being connected to other equipment.

Storage capacity-The amount of data an electronic medium will hold, usually specified in (8-bit) bytes. In this way, storage capacity can be calculated in terms of the type of information stored. The Compact Disc's 600 MB storage capacity, for example, can accommodate about 150,000 pages of typed text, about 72 minutes of the finest quality sound, or about 5000 frames of video-quality pictures.

System software-Programs that enable a computer to function and control its own operation, as opposed to application programs, which perform user-specific tasks. The most common type of system software is the group of programs that comprise the computer's operation system.

Template-In OCR, a stylized character pattern in computer code that is matched against scanned pixel data to recognize a letter or number.

Turnkey system-Any packaged configuration of integrated hardware and software that is designed to accomplish a particular information-processing task. The term is applied most often to dedicated computer systems that use minicomputers or microcomputers.

Vector data-A data base that contains a digital description of an image stored as a series of points and mathematical functions to describe the geometric figure, i.e., line, circle, arc, etc.

Video-A system of recording and transmitting primarily visual information by translating moving or still images into electrical signals. These signals can be broadcast via high-frequency carrier waves or sent through cables on a closed circuit.

Videodisc-A generic term describing an optical disc that stores color video pictures and two-channel sound along a spiral track. Uses the same optical readout principle as Compact Disc, but the discs are larger (30 cm in diameter) and double-sided, and the rotational speed and data rate are higher. The program information is analog, although the control information is digital.

WORM (Write Once, Read Many)-An optical disc technology in which the user may write to the disc as well as read from it.

Write-To transcribe recorded data from one place to another, or from one medium to another. (information from a computer is written to a disk, rather than on a disk.)

Write-Once Medium-A data storage medium to which data can be written but not erased.

Zoom-In video and photography, the facility to enlarge (zoom in on) or diminish (zoom out from) an area of an image.

APPENDIX B

TIME AND MOTION ANALYSIS RESULTS

The following data were obtained during our time and motion analysis conducted aboard an aircraft carrier and two submarine tenders.

A. MANUAL SYSTEM

We measured the time it took five different people to file 100 documents each into the filing cabinets. We then determined the average filing time per document for all five people.

1. FILING

SHIP	NR. FILED	TIME TO FILE	TIME/DOCUMENT
Carrier	300	248 Minutes	.83 Minutes
Sub Tender	200	126 Minutes	.63 Minutes
Overall	500	374 Minutes	.75 Minutes

2. RETRIEVING

We measured the time it took three different people to retrieve 50 documents each from the filing cabinets. We then determined the average retrieving time per document for all three people.

SHIP	NR. SEARCHED	RETRIEVAL TIME	TIME/DOCUMENT
Carrier	50	272 Minutes	5.44 Minutes
Sub Tender	100	226 Minutes	2.26 Minutes
Overall	150	498 Minutes	3.32 Minutes

SHIP	NR. SEARCHED	NR. NOT FOUND	% NOT ON FILE
Carrier	50	25	50
Sub Tender	100	17	17
Overall	150	42	28

B. ULTRA RETRIEVE, VERSION 1

We measured the time it took one operator to file 100 barcoded documents, scanning each document's index numbers with the LOGMARs barcode scanner, and the time to file 100 non-barcoded documents, entering index numbers via the keyboard.

DOCUMENT TYPE	NR. FILED	TIME TO FILE	TIME PER DOCUMENT
Bar coded	100	64 Minutes	.64 Minutes
Non-barcoded	100	112 Minutes	1.12 Minutes

APPENDIX C

AVERAGE NUMBER OF DOCUMENTS FILED AND RETRIEVED

A. DOCUMENTS FILED

The following data were obtained from COMNAVAIRLANT, COMNAVAIRPAC, and COMSUBPAC.

1. ISSUES

SHIP	AVE/SHIP/YEAR	AVE/SHIP/MONTH	AVE/SHIP/DAY*
Carrier	95,180	7,932	361
Sub Tender	54,288	4,524	206
Average	74,734	6,228	283

2. RECEIPTS

SHIP	AVE/SHIP/YEAR	AVE/SHIP/MONTH	AVE/SHIP/DAY*
Carrier	68,571	5,714	260
Sub Tender	61,975	5,165	235
Average	65,273	5,440	247

3. ISSUES AND RECEIPTS

SHIP	AVE/SHIP/YEAR	AVE/SHIP/MONTH	AVE/SHIP/DAY*
Carrier	163,751	13,646	621
Sub Tender	116,263	9,689	441
Average	140,007	11,668	530

* Based on 22 working days per month

B. DOCUMENTS RETRIEVED

In discussions with the ships' stock control and quality assurance officers, the divisions' personnel spend approximately two manhours per day (total) retrieving documents. To find the average number of documents retrieved per day, we performed the following calculation:

120 minutes / 3.32 minutes per document[10] = 36.14 or 36 documents per day

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[10] From Appendix B

APPENDIX D

ESTIMATED DOCUMENT FILE AND RETRIEVAL TIMES FOR PC-BASED SYSTEM

A. DOCUMENT FILING

(times based on 100 documents unless otherwise stated)

Document Preparation	10 minutes
Machine Scanning/Indexing	10 "
Indexing documents with unreadable index fields.	10 "
Total Filing Time for 100 documents	30 minutes
Ave. Nr. documents filed per day	533
Ave. Filing time per day (30 * 5.33)	160 minutes
System set-up time	5 minutes
Total average filing time per day	165 minutes
Ave. filing time per document (165/533) * 60 seconds)	19 seconds

<u>Document preparation</u> is the time needed to get the documents ready for the system to scan them. It consists of the following steps:

1. separate barcoded documents from non-barcoded documents,
2. separate documents with torn or frayed edges or smudged characters or bar codes that the scanner cannot read or process through the automatic document feed hopper,
3. Make sure all documents are face up and right side up.

<u>Mechanized filing</u> is estimated at 6 seconds per document. Ultra Retrieve version 2 can currently scan a document in 4 seconds. Based on their efforts to date, CACI engineers tell

us the automatic scanning and indexing time takes no longer than 5 seconds per document. We added a second for conservatism.

We assume the system will be able to read 90 percent of all document index fields. Therefore, 10 out of every 100 documents require the operator to enter the index numbers via the keyboard. We estimate this will take 1 minute per document based on our time-motion-analysis for filing non-barcoded documents with Ultra Retrieve, Version 1. Although Version 1 took an average of 1.12 minutes per document, it also required entering all of the receipt information on the barcoded document, instead of just the requisition number and NSN. By eliminating the extraneous information (i.e., routing identifier, quantity, unit of issue, etc.) we feel 1 minute per document is a conservative estimate.

<u>System set-up</u> consists of the time needed to power-up all system hardware components and proceed through the application software menus until the scanner is ready to start scanning documents.

B. DOCUMENT RETRIEVING

Ultra Retrieve version 2 took only 10 seconds to retrieve a document. This includes the time to key the index number, search for the document image, and display it on the screen. We do not expect the retrieval time to change with the new system.

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